HANDBOOK OF

TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS

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TECHNICAL INSTRUCTION FOR WIRELESS TELEGRAPHISTS

BY

J. C. HAWKHEAD

SECOND EDITION

EXTENSIVELY REVISED AND ENLARGED

BY

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PREFACE TO THE FIRST EDITION

Owing to the rapidly increasing demand for wireless telegraphists and to the necessity for their acquiring a certain standard of efficiency in compliance with Regulations set up by an International Body, it has become necessary to introduce a Handbook for the instruction of operators.

It can readily be understood that the wireless telegraphist at sea must have a much more comprehensive knowledge of the apparatus than the land telegraphist, as he cannot depend upon linesmen or engineers to repair any faults which may occur, and, in fact, is usually absolutely responsible for the efficient working of his station. As the ranks of wireless operators are usually recruited from some branch of land working, it is necessary for the men to receive additional tuition. This will be the excuse for the introduction in this book of a great deal of elementary matter which can also be found in multitudinous text-books.

The author wishes to thank Mr. H. Doboll, Superintendent of Instruction to Marconi's Wireless Telegraph Co., for his many suggestions and his careful reading and correction of the proof matter.

J. C. HAWKHEAD.

PREFACE TO THE SECOND EDITION

The constant demand for this Handbook, which has exhausted several reprints of the first edition, is sufficient evidence that it has been accepted by operators, students, and a large body of other readers, as a useful contribution to the literature of Wireless Telegraphy.

The publishers have thus been encouraged to issue a second and enlarged edition, which it is hoped will be found to deserve an equally good reception.

As the original author, Mr. J. C. Hawkhead, has taken up a permanent appointment abroad, the publishers were not able to obtain his further services. The necessary work of revision and amplification was therefore entrusted to the writer.

The large amount of new matter which has been added, includes forty-seven new illustrations, and eighty-eight of the original diagrams have been redrawn.

Part III. has been completely recast.

The Handbook is now up to date as regards wireless practice in Marconi small power stations up to 5 k.w. capacity. The requirements of the operator have made it necessary to give full descriptions of both old and new type apparatus, as the several thousand ships now equipped have been fitted at different dates, and apparatus of every type is therefore to be found on them. The student, as distinct from the operator, is thus provided with an illustration of the progress of Wireless practice, which he will no doubt appreciate.

H. M. DOWSETT.

CHELMSFORD,
September, 1915.

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CHAPTER I.

PRELIMINARY CONSIDERATIONS.

Electricity, derivation of—Production by friction—Coulomb—Potential—Electro-motive force (E.M.F.)—Volt—Ampère—Conductors—Insulators—Resistance—Ohm—Current electricity—Circuit.

AN operator with only a "tapping" acquaintance with his instruments knows that these depend for their action upon electricity. The word *electricity* derives its origin from the Greek word "elektron," meaning "amber."

Several hundred years ago it was discovered by scientists that a piece of amber rubbed with silk acquired certain properties. It was found that it acquired temporarily the power of attracting certain light bodies, such as small pieces of paper, feathers, straws, etc.

Other substances were found to be similarly affected by friction. Such bodies were then said to be electrified, or were said to be charged with electricity. It is found that the forces of attraction exerted by such electrified or charged bodies vary with the amount of electrification present. Assuming then that electricity has physical magnitude, it must be capable of measurement; hence the necessity of a standard unit. As the "foot" and "gallon" are units for linear and liquid measurement, so the "coulomb" is the unit of electric quantity. Thus a statement that a certain body is charged with, say, 20 coulombs of electricity, implies something similar to a statement that a tank contains 20 gallons of liquid.

The electricity thus produced by friction is in a stationary or non-moving state, being confined to the bodies between which the friction has been taking place.

The electricity used for telegraph purposes is a different type, being continuously in motion; and before we can

realise the idea of such motion it is necessary to consider another property possessed by this electricity. In order to transfer heat from one body to another, say from A to B, the temperature of A in the first case must be higher than that of B. Similarly, if a stream of water is to flow from one point to another, the pressure at the point from which it flows must be greater than the pressure at the point to which it flows.

The property of electricity corresponding to temperature and to pressure is known as "potential." Thus electricity will pass from any point at a certain potential to any point at a lower potential provided that a suitable path exists between the two points. It will be readily seen that the greater the difference of the potential between two points the greater will be the amount of electricity transferred during any period along the path, just as the amount of water transferred during a certain period depends upon the pressure exerted.

The difference of potential, therefore, determines, in addition to the direction of the motion of electricity, the amount of such motion. Hence potential difference is called electro-motive force, or E.M.F. For practical purposes the difference of potential must be measurable and the necessity for a unit arises. The name of this unit is the "volt."

If the student can imagine himself sitting on the bank of a river he will appreciate the fact that more water would flow past him in one hour than would pass him in one minute.

The passage of electricity along a suitable path takes place in a certain time. Consequently, when we are dealing with electricity in motion, it is necessary to take time into account. When one coulomb of electricity (that is to say, unit quantity) passes a certain point in one second (that is to say, in unit time), unit current is said to flow. The unit of current is called the "ampère."

We have stated above that the transference of electricity will only take place provided that a suitable path exists. Some materials are better adapted to the passage of electricity through them than others. Those materials through which the electricity passes with great facility are known as "conductors," and those through which the electricity passes only under great pressure, or in some cases apparently not at all, are called "insulators."

There is no such thing as a perfect insulator, and no such thing as a perfect conductor. This subject will be treated more fully later on.

Whenever we make an effort against any force we do work and are conscious of having expended energy. Whenever electricity passes along a conductor it does work, for it has to overcome a certain amount of resistance.

As the resistance offered by different materials to the passage of electricity through them varies in accordance with their dimensions as well as in accordance with the different material, it is necessary to have a standard unit in order that measurements may be made. The unit of resistance is the "OHM." Just as the sign " is used to represent inches so the sign "ω" (the Greek letter Omega) is used to represent "OHM."

So far we have only considered one method of generating electricity, viz. the application of friction to certain bodies. This method only produces electricity in extremely small quantities, and in a form which is useless to us for practical purposes, namely, the "static," or stationary form. It has been stated that the electricity for telegraph purposes is electricity *in motion*, or current electricity.

The current electricity of the type with which we shall deal first—continuous current—necessitates a complete path of conductors before it can exist. The complete path along which the current passes is called a "circuit."

Our attention will next be devoted to a study of the simpler methods of producing current electricity.

CHAPTER II.

PRIMARY CELLS.

Simple cell—Water analogy—Chemical action—Atom—Molecule —Element—Compound—Polarity—Kathode—Anode— Chemical equation—Polarisation, prevention of—Single-fluid cell—Léclanché cell—Dry cell—Double-fluid cell— Daniell cell, chemical action of—Saturated solution—Local action—Amalgamation.

IN the preceding chapter it was stated that a transference of electricity from one point to another along a conductor can only take place when a difference of potential or a difference of electrical pressure exists between these two points. Therefore, if we can devise some apparatus capable of producing potential difference, we shall satisfy the first requirements. This we find is a very easy matter, for, if two plates of different metals are immersed in acidulated water, we find that a difference of potential does exist, and if a suitable conducting path be made across the external portions of the plates, the conducting path will exhibit certain properties. It will be useful here to refer to the accompanying diagrams.

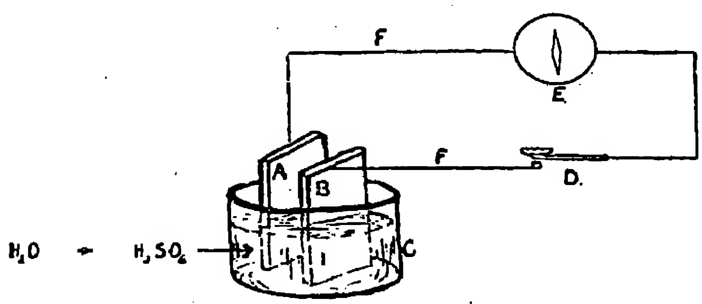


FIG. 1.—Simple Cell.

Fig. 1 represents the electrical circuit. A and B are plates of zinc and copper respectively, which can be placed at will in the vessel, C, containing water slightly acidulated with sulphuric acid. Between the upper extremities of A and B a copper wire, FF (copper being a good conductor), is joined. E is an instrument inserted in the copper wire circuit for the purpose of detecting the passage of electricity. D is a key by means of which we can make or break the circuit.

In Fig. 2 a jar, J, containing water, is connected by means of a rubber tube, T, to the glass tube, G. This arrangement we will call the water circuit. It will readily be understood that when the level of the water in the jar and in the tube is the same no water can pass from jar to tube. If, however, the jar, J, be raised to a higher level, water will flow through the rubber tube into the tube, G. The action of the electric circuit is very similar. If the plates, A and B, in the vessel, C, are both of the same metal, whether zinc or copper, there will be

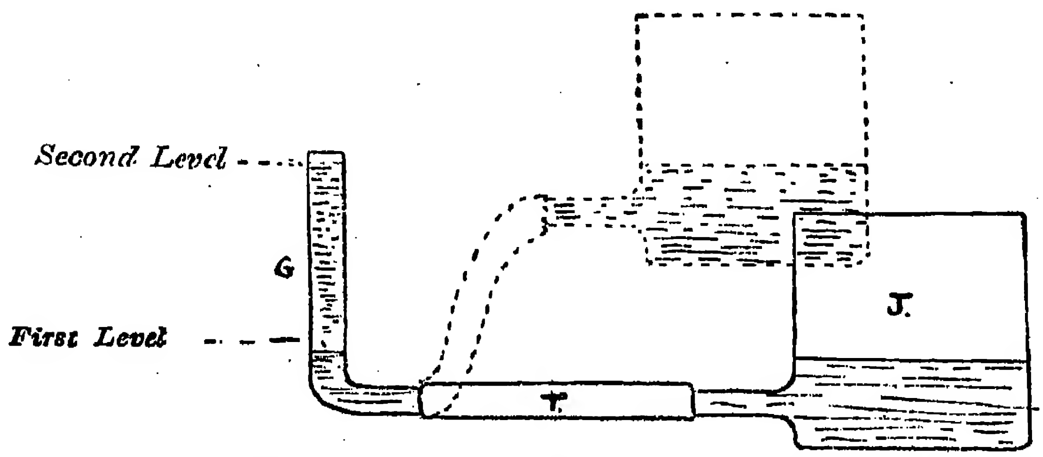


FIG. 2.—Hydraulic Analogy of Electric Circuit.

no passage of electricity when the key, D, is depressed; but if one plate of each metal is used, a passage of electricity is at once indicated. There is a difference of electrical pressure between the two plates which corresponds to the difference of water pressure in the two containers, J and G, due to their difference of level. As the rubber tube offers a path for the passage of the water, so the copper wire affords a path for the passage of electricity. If a stopcock be inserted in the rubber tubing it would perform a similar function to that performed by the key in the electrical circuit.

Simple Cell.—Such an arrangement of unlike metals immersed in a vessel containing acidulated water is known as a cell. It is found that when the circuit is complete bubbles of gas are given off from one of the plates and the other plate is gradually eaten away. Let us consider what action takes place in the particular cell just described. The action is of a chemical nature, and a few words of explanation are necessary for the proper understanding of chemical action. A substance

which cannot be chemically subdivided is called an element. Thus, copper, which cannot be split up into anything else but copper, is an element. Copper can, however, be chemically combined with other elements. Such a combination is known as a compound. Elements and compounds are represented symbolically. The smallest portion of an element which can take part in chemical action is called an "atom." The smallest quantity of either element or compound which can have independent existence is called a molecule. Thus, Cu represents one atom of copper. It also represents one molecule of copper as there is only one atom in the molecule.

Copper can be combined with sulphur and oxygen to form a compound called copper sulphate.

A molecule of this compound would be represented by $CuSO_4$, implying that it contains one atom of copper, one atom of sulphur, and four atoms of oxygen.

Whenever chemical action takes place a rearrangement of the atoms of the different elements is the result. It is easily seen, therefore, that chemical action can be represented by means of an equation.

The simple cell just described is known as a single-fluid cell on account of the fact that only one liquid is used. Its action is presumed to be as follows :—

The liquid (sulphuric acid) is decomposed—that is to say, it is split up into its component parts. One of these is a combination of oxygen and sulphur and another is hydrogen. The oxygen-sulphur combination (or "SO_4 radical," as it is called) attacks the zinc and combines with it to form zinc sulphate, and the hydrogen is evolved at the copper plate in the form of bubbles. The potential of the chemically attacked zinc plate is higher than that of the copper plate. A transference of electricity therefore takes place from the zinc to the copper through the liquid in the cell, returning from the copper through the external path back to the zinc.

Because the chemically attacked zinc is at a higher potential than the copper, it is said to be positive with respect to the latter. The zinc and copper plates are known as the "elements" of the cell, and are respectively the positive and negative elements. The external portions of the elements are supplied with terminals, or binding-screws, and are known as the "poles." As the current flows externally from the

copper to the zinc the former is called the positive pole and the latter the negative pole. Thus great care must be taken not to confuse the poles and the elements. The negative element is also called the kathode, and the positive element the anode, these words denoting the exit and entrance respectively of the current with regard to the cell. The following diagram will sufficiently illustrate this form of simple cell (Fig. 3).

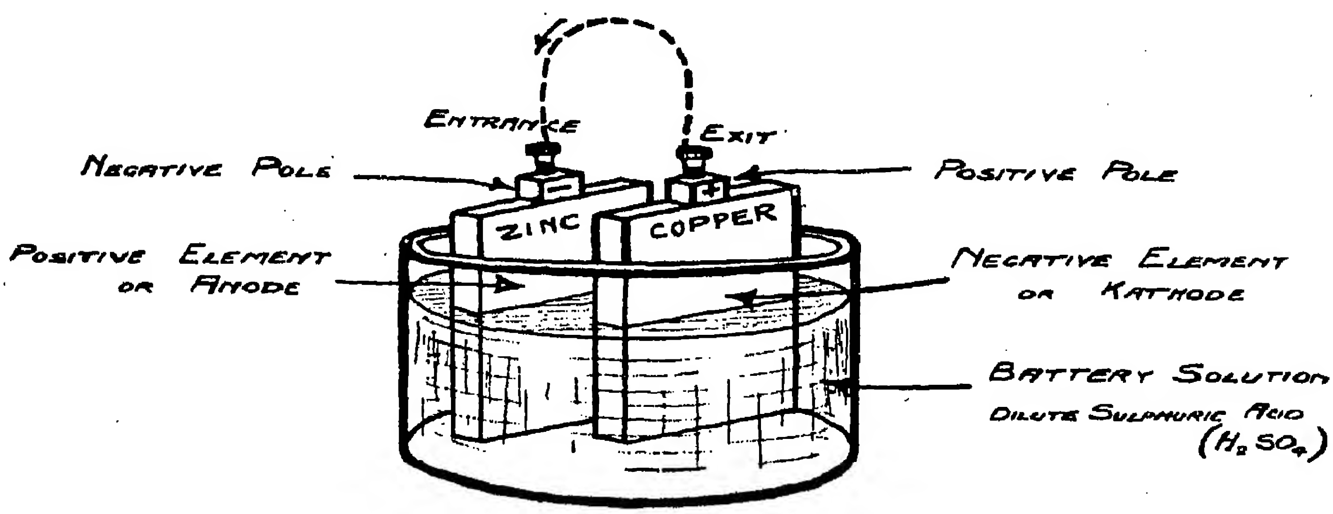


FIG. 3.—Composition of Simple Cell.

The chemical action which takes place can be represented by the following equation :—

Zinc + Sulphuric Acid = Zinc Sulphate + Hydrogen,

or, symbolically—

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

Other substances than copper and zinc may be used as elements, such as platinum and zinc, carbon and zinc, etc. The positive element is that which is most readily attacked by the acid.

Polarisation.—It has been stated that bubbles of hydrogen are evolved at the copper plate. Some of this hydrogen rises to the surface of the liquid and escapes into the air. A part of it, however, adheres to the copper plate, and after the cell has been working for a short space of time the plate becomes almost covered with a thin film of hydrogen. The hydrogen is found to have a much higher potential with respect to the zinc than the copper has, and the consequence is, of course, that the difference of potential between the two plates is decreased. Hydrogen also offers a greater resistance to the passage of electricity. It is seen, therefore, that a cell

of this type very rapidly loses its efficiency. When the copper plate has become covered with the film of hydrogen the cell is said to be "polarised."

The potential of the zinc element is 1·86 volts and that of the copper element ·81 volt. The effective difference of potential or E.M.F. is therefore expressed by $1{\cdot}86 - {\cdot}81 = 1{\cdot}05$ volts. Now, the potential of hydrogen is about 1·3 volts. The difference of potential at polarisation therefore becomes $1{\cdot}86 - 1{\cdot}3 = {\cdot}56$ volt. The polarisation of a single-fluid cell can be reduced by such devices as roughening the surface of the negative element or by keeping it in motion. Neither of these devices, however, are much used in practice. To get over this trouble another type of cell is designed in which provision is made for the combination of the hydrogen with other substances immediately it is produced.

The Léclanché Cell.—This is perhaps the best known of this type. It usually consists of a square glass jar containing

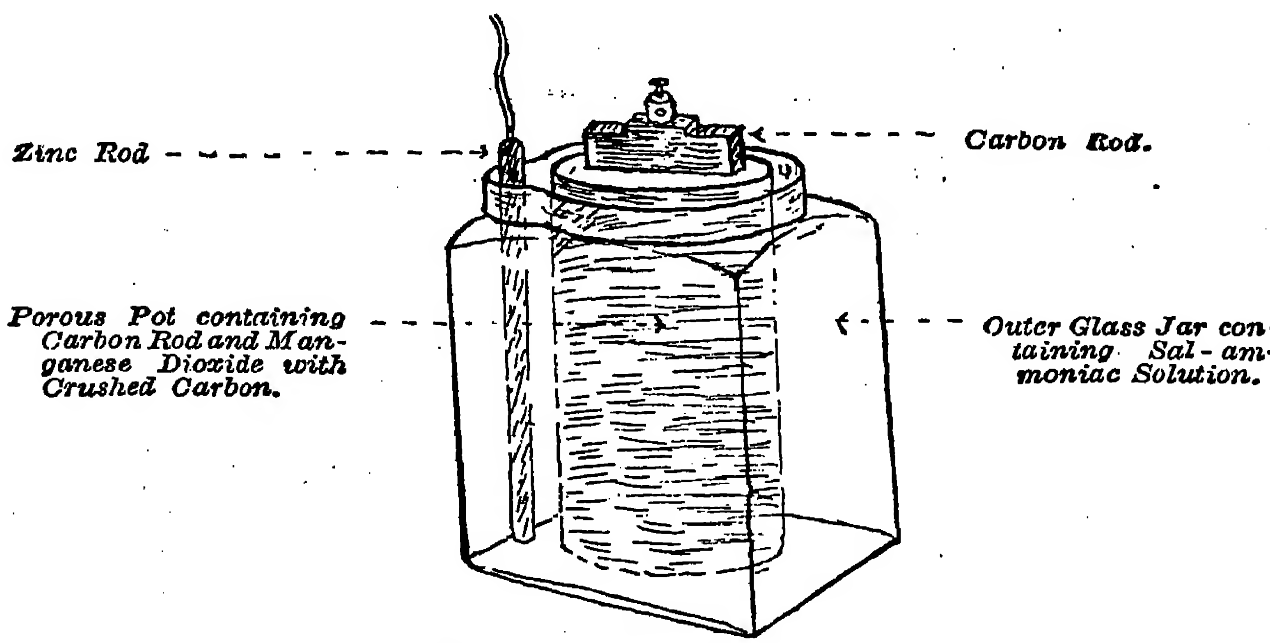


FIG. 4.—Léclanché Cell.

a saturated solution of ammonium chloride, which is known commercially as sal-ammoniac. A porous pot, containing a carbon rod in the centre packed round with manganese dioxide (MnO_2) and crushed carbon, is placed inside the glass jar. The top of the porous pot is sealed with pitch, a small hole being left for the escape of the gas produced by chemical action. The carbon is the negative element. A zinc rod is also placed in the sal-ammoniac solution, thus providing the

positive element. The porous pot allows the solution to make good contact with the crushed carbon and manganese dioxide (Fig. 4).

The action of this cell is as follows :—The sal-ammoniac attacks the zinc, forming a double chloride of zinc and ammonium. Hydrogen is liberated, which combines with a certain amount of oxygen, supplied by the manganese dioxide, to form water, thus preventing the polarisation of the carbon or negative element.

The Dry Cell (Fig. 5).—A very common type of primary cell, and almost the only type with which the average wireless

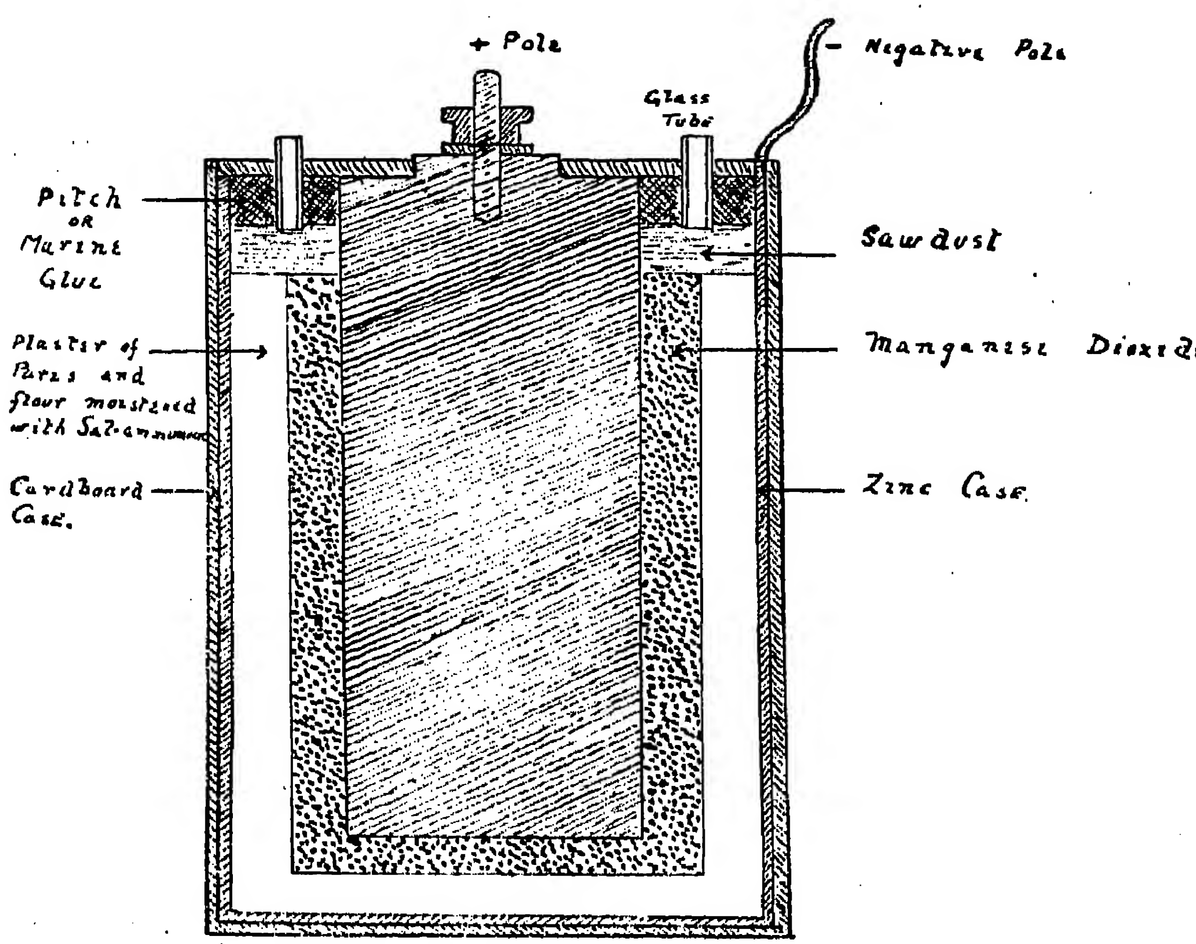


FIG. 5.—Section of Dry Cell.

telegraphist will come in contact, is known as the dry cell. The action of this cell is precisely the same as that of the "Léclanché." It possesses the advantages, however, of cleanliness and portability. This cell consists of a zinc case which acts as a container and at the same time as the positive element. It is protected and insulated on the outside by means of a cardboard sheath. In the centre is fixed a carbon

rod, carrying a terminal at its upper extremity, which is surrounded by a mixture of manganese dioxide and graphite or crushed carbon. Between this mixture and the zinc container a lining of plaster of Paris and flour, moistened with a saturated solution of sal-ammoniac, is placed. The top is filled in with a padding of cotton-wool or sawdust and sealed with pitch or marine glue, through which two small glass tubes run to afford an outlet for the gases produced by chemical action.

This cell cannot be used for any protracted period of time without polarisation taking place to some extent. The manganese dioxide only liberates oxygen—which, it will be remembered, combines with the liberated hydrogen to form water—slowly, and consequently after a certain time, more hydrogen is liberated than can be dealt with. If left for a little while, however, the cell recovers itself. It will be understood, therefore, that this type is very useful when intermittent service is required, as in the case of electric bells, etc.

The two cells described are of the single electrolyte type. Although it is very improbable that a wireless operator will have dealings with any other type of primary cell, a description of a cell of the double-fluid type may be useful.

The Daniell Cell (Fig. 6).—This cell is usually made up

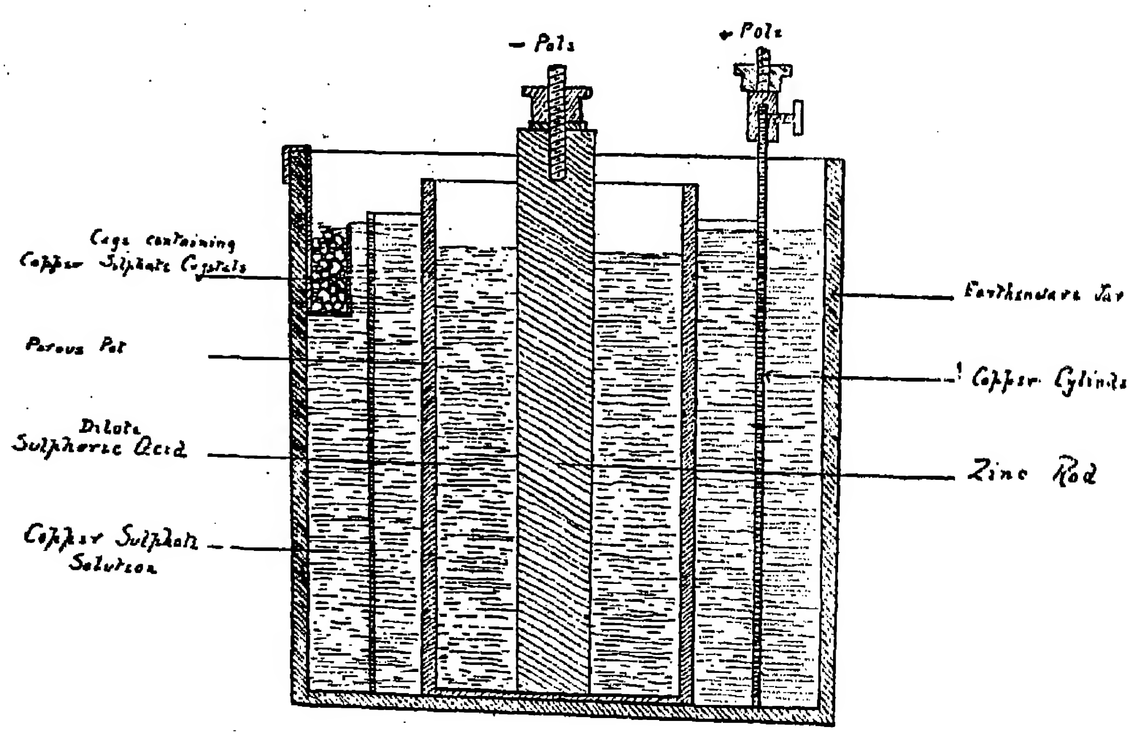


FIG. 6.—Section of Daniell Cell.

of an earthenware container with a porous pot inside it. The negative element is a copper cylinder, which rests in a saturated solution of copper sulphate, placed in the outer jar, and the positive element is a rod of zinc immersed in a dilute solution of sulphuric acid contained in the porous pot.

The action is as follows :—The zinc is attacked by the acid and gradually eaten away, zinc sulphate ($ZnSO_4$) being formed in solution. Hydrogen (H) is evolved at the copper plate and combines with the SO_4 group contained in the copper sulphate ($CuSO_4$) to produce sulphuric acid (H_2SO_4), which percolates through the porous pot and maintains the strength of the original acid. It will be seen that when the SO_4 group is taken from the copper sulphate ($CuSO_4$), copper should be left. As a matter of fact pure metallic copper is deposited on the copper plate in the form of a black powder.

The following equations illustrate the action :—

Before the circuit is complete.

Outer Jar.

Copper, Copper, Copper Sulphate.
$Cu \quad Cu \quad CuSO_4$

Porous Pot.

Sulphuric Acid, Zinc.
$H_2SO_4 \quad Zn$

After circuit is complete.

Porous Pot.—

Sulph. Acid+Zinc=Zinc Sulphate+Hydrogen.

$$H_2SO_4+Zn=ZnSO_4+H_2$$

Outer Jar—The liberated H_2 passes to the outer jar, where :—

Copper Sulph.+Copper Sulph.+Copper+Hydrogen=Sulph. Acid+Copper+Copper Sulphate.

$$CuSO_4+CuSO_4+2Cu+H_2=H_2SO_4+3Cu+CuSO_4$$

Saturated Solution.—In the descriptions of the Léclanché and Daniell cells use is made of the expression "saturated solution."

By a solution we understand the disappearance of a substance in a given liquid. A saturated solution is a solution containing as much of the substance as it is possible to dissolve.

When copper sulphate is added to water it will dissolve until a certain point is reached, after which any additional copper sulphate remains at the bottom of the vessel containing the solution.

In the case of the "Daniell" cell, it is seen that the copper sulphate is being continuously decomposed by the liberated hydrogen. In order to maintain the solution in the outer jar at a point of saturation, it is usual to provide a cage in which pure copper sulphate crystals are placed, which will gradually dissolve to replace that which has been split up during the production of pure copper and sulphuric acid.

Local Action.—In each of the cells described it is stated that the zinc element is gradually eaten away. This action

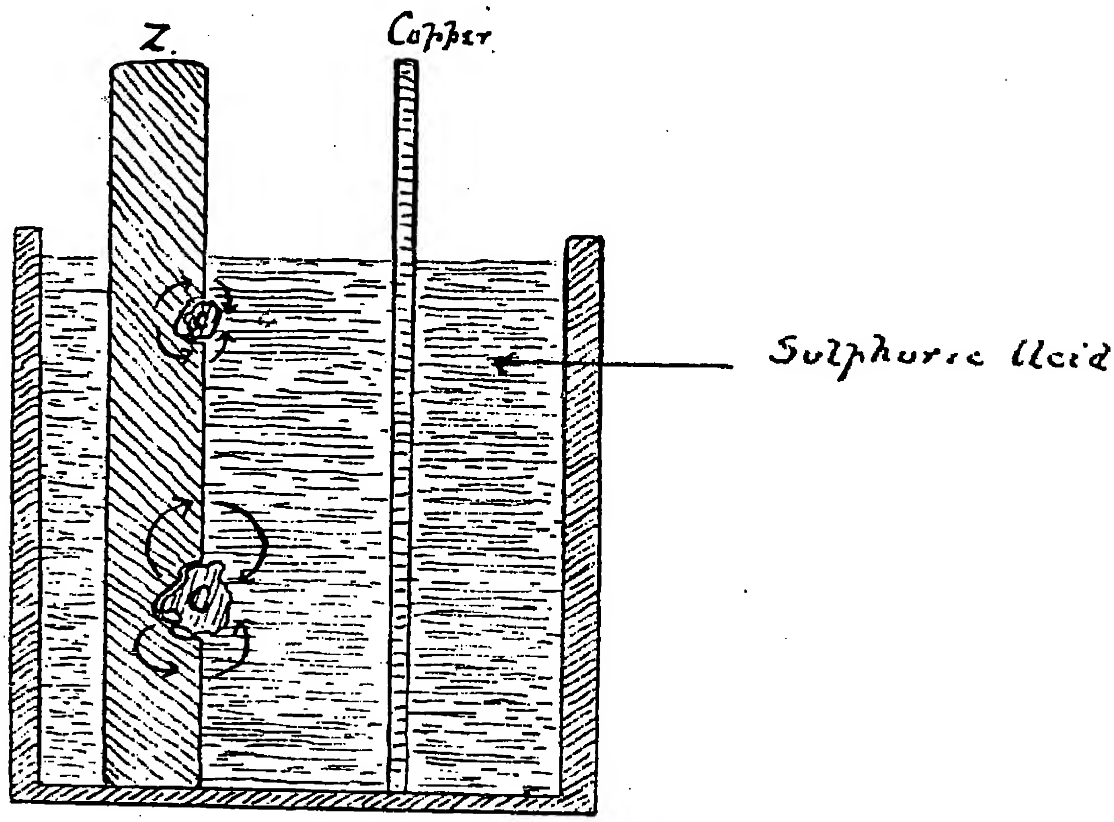


FIG. 7.—Local Action.

only takes place when the circuit is complete, but under certain conditions the eating away will be excessive. Commercial zinc invariably contains certain impurities, usually small quantities of such materials as copper, arsenic, lead, etc. When such impurities are on the surface of the zinc rod used in a cell the following action takes place. In the accompanying figure (Fig. 7) Z represents the zinc rod and C a particle

of copper impurity greatly magnified. When such a rod is immersed in dilute acid a local miniature cell is formed, the zinc being the positive element and the copper impurity the negative, the small space between being filled with dilute acid. Thus a zinc rod containing many impurities would be rapidly eaten away even on an open circuit.

Amalgamation.—Most metals very easily form an alloy with mercury, such alloys being called "amalgams," and the process producing them being known as "amalgamation." A zinc rod may be amalgamated as follows :—

Using a greasy cloth to prevent burning of the fingers, the zinc rod is first cleaned with dilute hydrochloric or sulphuric acid. Mercury is then rubbed over the rod until it presents a bright and shiny surface. When such an amalgamated zinc rod is used in a cell the zinc in the amalgam covers the whole surface of the rod exposed to the acid and the conditions for local action are thus prevented.

In the case of the "Daniell" cell local action is avoided in a different way. It will be remembered that zinc sulphate is spontaneously formed in the action of the cell. When zinc sulphate takes the place of the sulphuric acid local action is avoided. If, therefore, the action be allowed to take place for some time before the cell is actually required it becomes unnecessary to use anything more than water in the zinc cell at the commencement.

There are many other types of cells, such as the "Bichromate," "Bunsen," "Grove," etc., but as a knowledge of these types is not necessary, no description is given here.

CHAPTER III.

ACCUMULATORS.

Electrolysis—Electrolyte—Electrodes—Ions—Simple accumulator or secondary cell—Commercial accumulator—Plates, positive and negative—Containers—Separators—Theory of specific gravity—Hydrometer—Hicks's suction hydrometer—Charging—Test for polarity of charging mains—Gassing—Discharging—Sulphating—Buckling—Local action—Evaporation—Growths—Management of accumulators—Treatment when not in use.

Electrolysis.—Just as chemical action can be utilised for setting electricity in motion, as described in the previous chapter, so electricity in motion is capable of setting up chemical action. When a current is sent through certain liquids, they are split up into their component parts. If a

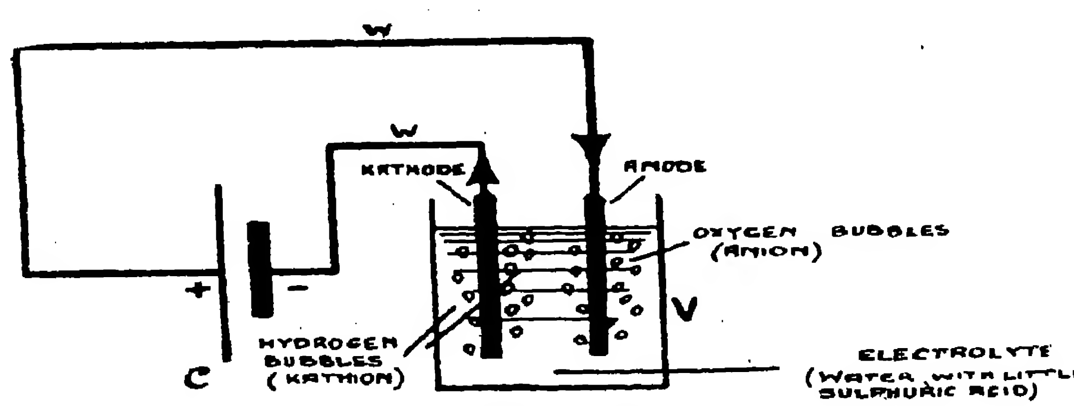


FIG. 8.—Electrolytic Cell.

current is sent through water, which is a combination of the gaseous elements hydrogen and oxygen represented by the formula H_2O, the water is split up into these two gases. Thus if C represents some form of primary cell, and V is a vessel containing water, when the ends of the wire W are placed in the water, bubbles of gas arise at either end of the wire,

which on examination prove to be bubbles of oxygen and hydrogen respectively. If a little sulphuric acid be added to the water the action is increased, as the liquid then offers less resistance to the passage of the current—indeed, perfectly pure water is a non-conductor.

The process which decomposes the liquid by the passage of a current is called "electrolysis," the liquid being known as the "electrolyte," and the ends of the conducting wires "electrodes."

The whole arrangement of the vessel, electrolyte and electrodes, is known as an electrolytic cell, and the electrode at which the current enters is called the "anode," the one at which it leaves being called the "kathode."

The substances into which the electrolyte is split up are called "ions," and as the hydrogen appears at the kathode it is called the "kathion," the oxygen being called the "anion."

During the electrolysis of any solution which results in the formation of hydrogen or any of the metals, the latter travel with the current, and as this passes inside the cell from the anode or leading-in electrode to the kathode, hydrogen and the metals are deposited on the leading-out electrode or kathode.

The formula of water has been given as H_2O, implying two atoms of hydrogen to one of oxygen in every molecule. Experimentally it is found that two volumes of hydrogen are given off to one of oxygen.

Here, therefore, we have a simple method of finding out the positive and negative poles of a cell or other source of current, for, if the source of supply be connected up to a simple electrolytic cell, gas will be given off more freely at the electrode in connection with the negative pole.

Simple Accumulator.—If lead plates are attached to the ends of the conducting wire immersed in the dilute acid several changes are found to take place when the current is passed through. The strength of the acid is affected, and changes take place in the composition at the surfaces of the lead plates. These changes will be discussed more fully later.

If the primary cell is now disconnected from the electrodes, and an external circuit closed upon these, a current is found to flow, and gradually the plates are found to approach their original state and the acid its original strength.

When a certain point has been reached the cell is found

to be incapable of producing further current. To summarise the above, we find that by passing a current through the electrolyte and electrodes we have produced a type of cell capable in turn of producing a limited amount of current. Such an arrangement is therefore called an "accumulator," storage battery or secondary cell. The names "accumulator" and "storage battery" are really misnomers, as they do not store up a supply of electricity; they do, however, store up some of the energy supplied to them. What really happens is that the electricity supplied produces chemical action, and when the supply is cut off and an external circuit joined across the electrodes an opposite chemical action in the secondary cell sets electricity in motion. The chemical action in the first case has converted one of the lead plates into lead peroxide (PbO_2), and we thus have two dissimilar plates immersed in dilute acid as in the case of the simple cell.

Commercial Accumulators.—A simple accumulator of the type just mentioned would be of very little use for practical purposes, and considerable modifications are necessary. It will be readily understood that the greater the surface presented to the electrolyte the greater will be the action. For this reason the practical accumulator is usually made up of several positive and negative plates grouped as in the accompanying diagram (Fig. 9). There is always one more negative than positive plate in order that both sides of every positive plate may be acted upon.

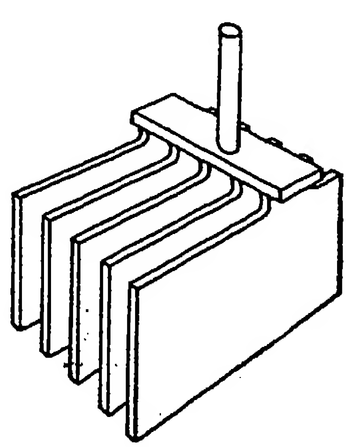


FIG. 9.—Group of Accumulator Plates.

The positive plate consists of a frame made of lead strengthened with antimony, containing a number of holes into which a paste made of red lead and sulphuric acid is pressed.

The negative plate is made of chemically pure lead. Each cell consists of one set of positive and one set of negative plates fixed in a container, which for use at sea usually consists of a lead-lined teak box. As it is extremely important that the opposite plates do not touch at any point, separators are introduced which usually take the form of glass rods, perforated ebonite or celluloid sheet, or thin wooden boards of specially prepared wood. In the type of accumulator used at sea the separators are of the last-mentioned type, and an idea of their

appearance will be better gathered from the accompanying diagram (Fig. 10).

It will be seen that the boards are grooved on either side, this being to allow the acid to have better access to the surface of the plates. The plates when packed for transport are generally separated by distance-pieces of ordinary wood. These must be removed without fail and replaced by the proper separators before putting in the electrolyte. The edges of the two kinds of plates are prevented from making contact along the lead lining by means of ebonite sheets at the sides, and by being supported on an insulated rack set in the bottom of the container, a diagram of which is given (Fig. 11).

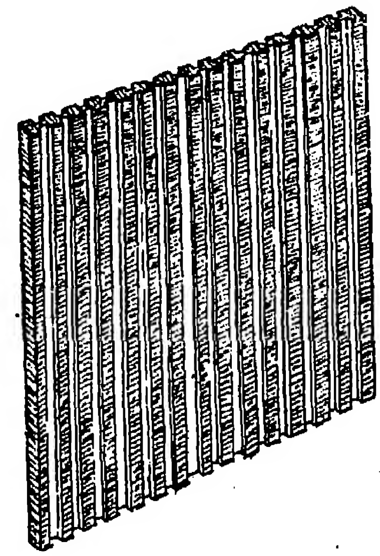


FIG. 10.—Wooden Separator of Accumulator.

The Action of the Accumulator.—When such accumulators are received from the manufacturer they invariably require a long initial charge. That is to say, a current from a dynamo or primary battery must be sent through them for at least thirty hours. This current produces chemical action, which results in the negative plate being composed of pure lead in a spongy state, while the positive plate is composed almost entirely of lead peroxide.

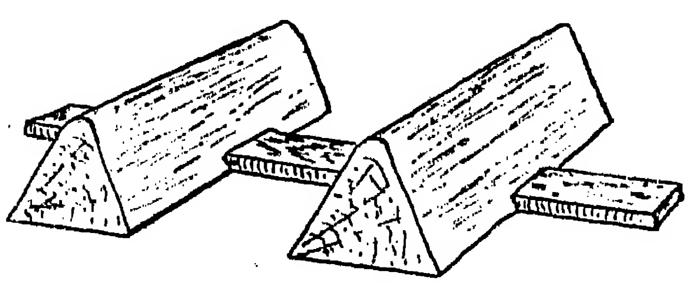


FIG. 11.—Insulating Stand for Accumulator Plates.

After a normal discharge —that is to say, after as much current has been taken from the accumulator as is consistent with the well-being of the plates—about half the lead in the negative plate and half the lead peroxide in the positive plate is converted into lead sulphate. At the same time the strength of the acid drops, as part of it is taken up in the formation of this sulphate. The strength of the acid is therefore a good indication of the condition of the cell.

When charging, the action is exactly the reverse, the plates are once more converted into their original state and the acid rises to its original strength, provided the accumulators are in good condition.

The Hydrometer.—An instrument called a hydrometer is used for testing the specific gravity of the acid. It indicates the proportion of the weight of a given volume of the liquid to the weight of an equal volume of water at the same temperature. Different types of accumulators require acid of slightly varying strength. That made by the Chloride Accumulator Company requires acid of an initial specific gravity of 1·215. That is to say, if one cubic centimetre of water weighs one gramme, one cubic centimetre of this acid weighs 1·215 grammes.

There are several different types of hydrometers. When a body floats in any liquid we know that the weight of the

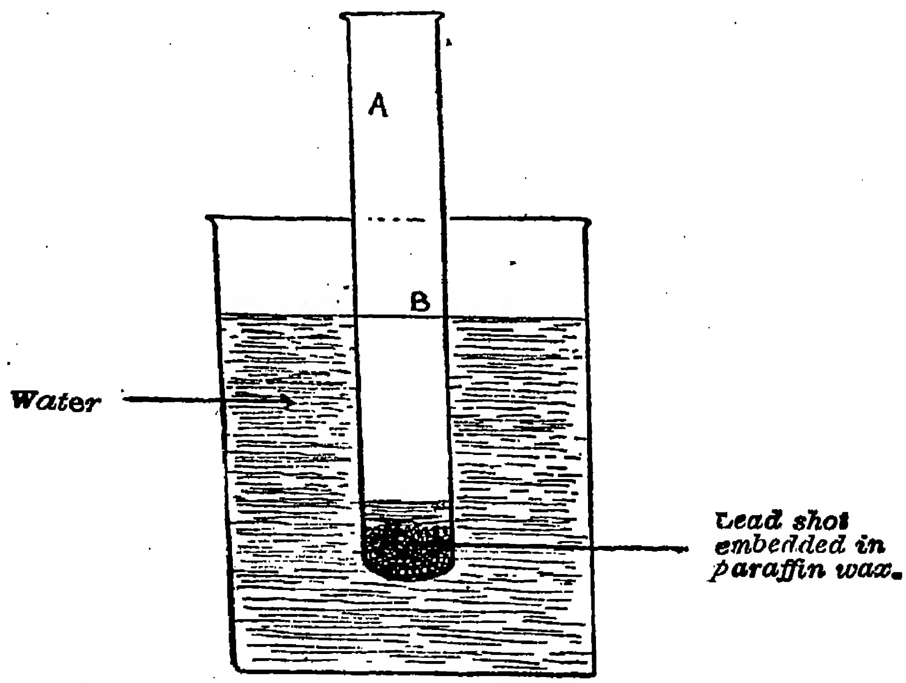


FIG. 12.—Construction of Hydrometer.

liquid displaced is equal to the weight of the body. A simple hydrometer may therefore be made as follows :—Into a tube, A (Fig. 12) a sufficient quantity of lead shot is placed—held in position by paraffin wax—to make it float in water up to, say, the level B. If this water be at a temperature of 4 degrees centigrade this level represents a specific gravity of 1. Different standard solutions of known specific gravities may then be taken, and it will be found that the tube will float in them so that more or less of it will be immersed. Thus in alcohol and certain oils the tube would sink deeper because their specific gravities are less than that of water. In a solution of salt or sulphuric acid the tube would be less deeply immersed, indicating a greater specific gravity. If then, as

stated above, certain standard solutions be taken, a graduated scale can very easily be marked on the outside of the tube. For taking the specific gravity of the acid in accumulators this type is not very convenient, as the plates usually occupy all the space in the container. A form of hydrometer known as "Hicks's Suction Hydrometer" is therefore very often employed. This consists of a glass tube, as shown in Fig. 13, fitted with a rubber teat very similar to the ordinary fountain pen filler. Inside this tube are different-coloured glass beads, each of which would float in a liquid of a certain specific gravity. A table is supplied with the instrument giving the specific gravities corresponding to the different beads. In order to test the specific gravity of the acid in an accumulator, it is only necessary to insert the end of the tube in the liquid and to squeeze and release the teat, which excludes the air and allows a little of the acid to fill the tube. The reading corresponding to the particular bead which floats nearest the centre of the tube gives the specific gravity of the acid. In the type supplied to operators the specific gravities indicated are :—

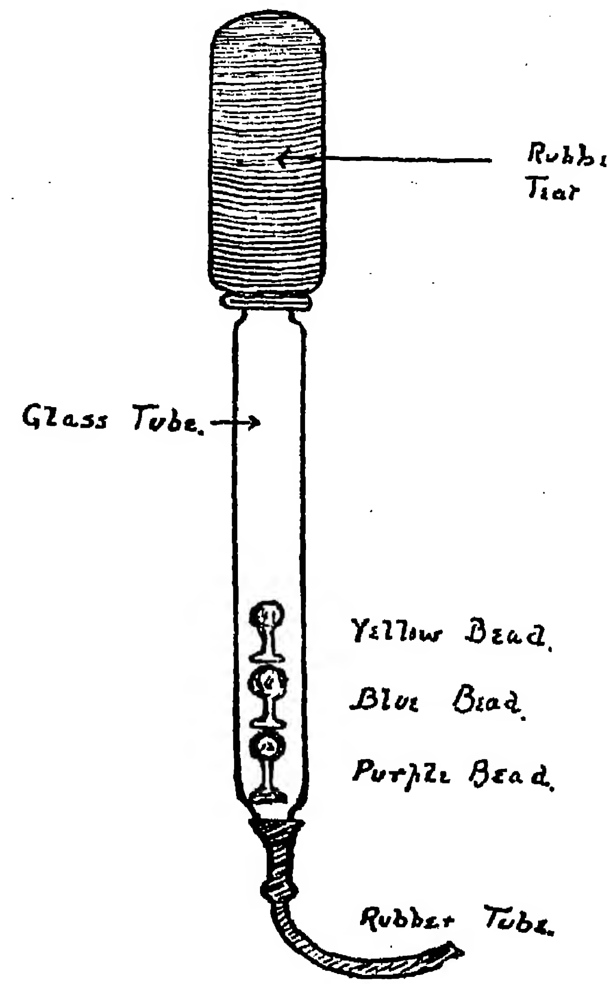


FIG. 13.—Hicks's Suction Hydrometer.

Yellow	1·170
Blue	1·185
Purple	1·200

Charging.—As previously stated, new cells require a long initial charge, and great care must be taken that certain conditions are satisfied before commencing. The positive pole of the source of supply of the charging current must be connected to the positive pole of the accumulator battery, and

the negative pole to the negative. A method of distinguishing the polarity of the charging loads has been mentioned under the heading of "Electrolysis," where it is stated that gas will be more freely liberated from the electrode in connection with the negative pole of the source of supply.

In order to test properly for polarity two small pieces of lead should be connected to the ends of the two supply mains, these pieces of lead forming the electrodes of the simple electrolytic cell; a resistance such as a lamp being included in the circuit if the voltage is high. It would be seen that the electrode from which gas was being evolved less freely would turn brown, due to the formation of lead peroxide. As a rule, lead-covered cable is used in a wireless installation, and strips of the lead sheathing may be conveniently used for this test. Another simple way of testing is by pressing the end of the two leads on to a piece of damp blue print paper. The paper under the negative lead turns white.

The positive pole of the accumulator can be recognised as follows:—It is always of a chocolate-brown colour, and

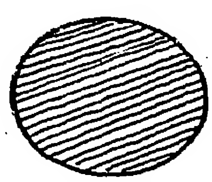


FIG. 14.—End View of Positive Pole.

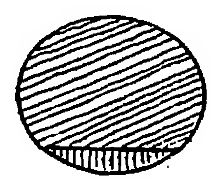


FIG. 15.—End View of Negative Pole.

the paste can readily be recognised in the lead frame. All the positive plates in a cell are joined together by means of a lead strip, which is usually painted red, and the pole piece is generally insulated from the cover of the container by means of a piece of red rubber tubing. In the type of accumulator supplied to ships the pole piece is of round section, and the upper extremity appears as a circle (Fig. 14).

All the negative plates are similarly joined together by means of a lead strip or bar, but in this case it is painted black, and the insulating tube is of black rubber. The pole piece is generally filed in such a manner that its upper extremity appears as in Fig. 15.

The outside of the container and cover are also marked with the following signs:—

Positive + Negative —

When building up an accumulator cell great care must be taken that the plates are so placed in the container that the poles coincide with these marks. Before making the actual connections between the dynamo and the accumulator battery, it is necessary to see that the former is delivering current at a greater pressure than that which the battery can produce. Otherwise the battery would discharge itself through the dynamo, as its pressure is acting in an opposite direction to that of the charging current.

Assuming then that the charging current at our disposal is of suitable dimensions (its voltage should be at least 10 per cent. higher than that of the battery), the acid is put into the cells until it rises about half an inch above the level of the top edges of the plates, and the connections are made. The reason that the adding of the acid is left until all else is ready for the commencement of charging is that it would needlessly attack the lead plates if added earlier.

Suitable measuring instruments are used in the circuit, but these will be described later when dealing with a particular circuit actually used in a Standard Marconi Installation. These instruments indicate when the battery is fully charged or discharged.

An instrument called a voltmeter indicates the potential difference, but in order that this reading may be a true indication of the condition of the cell it must be taken when the cell is delivering current. When the cell is not delivering current it usually shows a pressure of two volts, which does not depend much upon the extent to which the cell has been charged or discharged. If a cell gives a pressure much below two volts when no current is passing it is usually in a very bad state.

As the process of charging continues, it is found that the specific gravity of the acid slowly rises. The voltage also rises, slowly at first and then more rapidly, until the difference of pressure between the poles of each cell is about 2·6 volts.

Now the specific gravity of the acid rises most rapidly in the parts adjacent to the plates. The difference of pressure depends to a great extent on the specific gravity. When the charging is stopped the specific gravity of the acid becomes uniform, and that of the part adjacent to the plates is slightly lowered, with a resulting decrease in pressure, and it is found that shortly after cutting off the charging current from a fully charged cell its potential difference drops to about 2·1 volts.

If the voltage of a cell fails to rise properly towards the end of the charge it is an indication that it is in a bad state.

Gassing.—A cell is fully charged when the specific gravity of the acid ceases to increase. After this point is reached the charging current is only being used to decompose the water in the cell into hydrogen and oxygen. Bubbles of these gases then rise to the surface. Usually there is a sufficient number of these small bubbles at the end of a charge to give the acid quite a milky appearance. The current required for charging accumulators varies in different makes, and of course the supply has to be regulated in accordance with the makers' instructions. When the correct charging current is used and the cells are gassing freely at both positive and negative plates, the current should be reduced to one-half and charging be continued until they once more begin to gas. At this point charging should be stopped.

Discharging.—The value of the current taken from the accumulators must not exceed the maximum specified by the makers. As current is taken away the reverse of the charging process takes place. The specific gravity and the voltage slowly drop. This drop must not be allowed to fall below certain limits. The voltage of a cell on a closed circuit should never be allowed to fall below 1·85 and the specific gravity below 1·170.

Faults—Sulphating.—The most common fault is known as sulphating. When the cell is being discharged it has been stated that lead sulphate has been formed on both plates. This lead sulphate is in such a form that it is easily soluble during the charging process under normal conditions. When a cell is discharged below the limits given, or even when a discharged cell which has not been allowed to discharge below these limits is left inactive for any length of time, the sulphate appears to work out to the surface of the plates in the form of crystals, which are almost insoluble and very difficult to remove. This sulphate is a very poor conductor, and offers great resistance to the passage of the current, and consequently the efficiency of the cell is very much impaired.

A sulphating cell may be easily detected because the specific gravity of the acid at the end of a charge will be less than it was at the end of the first charge. This is because the plates have not liberated as much acid during charge as they took up during discharge, as part of the acid has been

used to form the insoluble sulphate. The remedy for this is extra charging. The faulty cell must be cut out of the battery after a charge and replaced during the next charge. When a cell is very badly sulphated the sulphate is seen adhering to the plates, and it is extremely difficult to remove. In fact, it is often found cheaper to supply new plates.

Buckling.—When lead or lead peroxide is converted into lead sulphate, the latter has a much larger volume than either of the former materials. Actually the volume of lead sulphate is about twice the volume of a corresponding quantity of lead peroxide and about three times the volume of a corresponding quantity of metallic lead. When, therefore, an accumulator is discharging, the paste in the positive plates and the lead in the negative plates gradually expand. This expansion has a great tendency to cause buckling of the plates, and is largely responsible for the dropping in voltage during discharge. As the material expands it closes up the pores, thus preventing the acid from coming into contact with the whole amount of active material. This expansion of active material, together with violent gassing and local action—which is an action similar to that described in connection with the primary cell—results eventually in the disintegration of the plates.

In the type of accumulator supplied with wooden separators the buckling and disintegration are to a certain extent prevented.

If any foreign conducting matter is allowed to fall between the opposite plates the resistance at this point is lessened, and unequal action takes place with unequal expansion of different parts of the same plates, and a consequent twisting or buckling ensues.

Local Action.—Another type of local action than that already explained takes place in an accumulator. This takes place between the lead of the positive plate and the lead peroxide with which it is coated. This action is lessened more or less by the coating of lead sulphate which the action itself causes to be formed on the lead.

In order to reduce local action as far as possible great care must be taken that the electrolyte is as pure as possible when it is first made up, and that no metallic impurities are allowed to fall into the cell when in use.

Evaporation.—The liquid in the cell gradually shrinks in volume. This shrinkage is usually due to evaporation of

water, and must be compensated for by the addition of pure distilled water. Some loss also takes place on account of the splashing caused by gassing, but splash boards are usually supplied which fit closely over the top edges of the plates, and this loss is very small. Should any of the acid be accidentally spilled dilute acid of the original specific gravity must be added.

Growths on Plates.—If a flake of paste from the positive plate falls on to the negative plate it will discharge itself as well as that part of the plate on which it has fallen. During the next charge this projecting flake will be converted into spongy metallic lead, and during the ordinary working of the cell will tend to grow larger and larger, and if not removed may finally short circuit the cell by touching the opposing plate.

The Management of Accumulators.—Cells should not be discharged at a greater rate than that specified by the makers, nor should the discharge be continued beyond the point at which the voltage during discharge has dropped to the limit mentioned—*i.e.*, 1·85 volts.

Cells should not be allowed to remain discharged longer than necessary, and when they are charged they should be fully charged at a rate not exceeding that specified ; and prolonged or violent gassing should be avoided.

A watch should be kept on the specific gravity of the acid in each cell when the charge is apparently complete. If it is not up to standard strength in any cell that cell should be cut out of circuit during discharge and replaced during the next charge in order to remove any insoluble sulphate by extra charging. The action of sulphating is also indicated by an abnormal dropping of the voltage during discharge.

The level of the electrolyte must be kept above the tops of the plates as explained.

The cells should be regularly inspected to see if there are any flakes or growths in such a position as to be liable to short-circuit the cell. If found, they should be scraped off. The terminals should be coated with vaseline to prevent sulphating.

Treatment of Cells when Not in Use.—When a battery is to be left for any considerable time in an inactive state special steps must be taken to prevent deterioration. If it is to be left for only a month or so it is only necessary to give it an extra charge after seeing that each cell is in a good

condition. Should it be left for a longer period than this the following steps should be taken.

The battery should be given an extra charge, and after care has been taken that every cell is in a good condition, the acid should be poured off and the plates where possible, placed to soak in pure distilled water for about twenty-four hours. They should then be taken out of the water and allowed to dry, afterwards being replaced in the dry containers until required for further use. On being brought into active service again they must be given a long charge, as it is necessary to remove certain salts from the negative plate which are formed by oxidation due to exposure to the air.

In cases where it is possible to give the battery a prolonged charge about once a month, it is quite unnecessary to remove the acid, etc., as such periodic charging, combined with an occasional complete discharge, will keep it in a good condition for an indefinite time.

CHAPTER IV.

CURRENT ELECTRICITY: ITS LAWS AND UNITS.

Relation between current, E.M.F., and resistance—Ohm's law—Specific resistance—C.G.S. units—Series resistance—Parallel resistance—Arrangement of cells—Batteries—Arrangement for maximum current from given number of cells—Potential slope—Potentiometer.

Now that we have seen how electricity may be set in motion it becomes necessary to examine the conditions which decide its utility from a practical point of view.

That is to say, we must study the relationships which exist between Current, Potential Difference, and Resistance, and the application of the units by which these dimensions are measured.

A reference to Fig. 2 will help us easily to understand these relationships. The higher the jar J is raised with respect to the tube G, the greater will be the amount of water transferred to the latter in a given time. The raising of the jar of course determines the pressure exerted by the water contained in it.

If now the rubber tube T be removed, and another one of much smaller diameter be substituted, a less volume of water would pass through it in a given time than would pass through the original tube. If this tube were then filled with sand an even smaller quantity of water would pass in the same time. It is thus seen that the dimensions of the path through which the water flows affect the volume of the water allowed to pass in a given time.

If we turn to the electrical circuit shown in Fig. 1, we find an exactly similar state of affairs. The instrument E is capable of giving us an idea of the amount of electricity flowing in the circuit, a large deflection of the needle N indicating the passage of a higher quantity than that indicated by a small deflection.

We find by experiment that if the wires FF are replaced by extremely fine wires of the same material, a much smaller deflection of the needle results. The quality in virtue of which the wire affects the passage of electricity is its resistance, and we find that under certain circumstances the amount of current varies inversely as this resistance.

We understand by this that if the resistance be doubled the current will be halved, or that if the resistance be halved the current will be doubled.

Again, if by some means we can increase the difference of potential between A and B, we find the current is increased in a direct ratio, which is to say, that when the difference of potential is doubled the current becomes doubled, and if the difference of potential is halved the current becomes halved.

Ohm's Law.—From these two relationships a law known as "Ohm's Law"—named after a distinguished German physicist—has been formulated, viz. :—

Current equals Pressure divided by Resistance.

If the letter C be used to represent current, E to represent pressure or electro-motive force, and R to represent resistance, this law can be written thus—

$$C=\frac{E}{R}$$

Now the ampêre is the unit of current, the volt is the unit of E.M.F., and the ohm is the unit of resistance. Therefore in any circuit where two of these quantities are known it is easy to calculate the third. It is easily seen that the relationship existing between these units may be expressed as follows :—

In a circuit of one ohm resistance, a pressure of one volt will force a current through the circuit of one ampêre.

Resistance.—Now the resistance of any conductor depends on its size and on the particular material of which it is made.

Just as the internal diameter of a water-pipe determines its capacity for conducting a flow of water, so the cross-sectional area of a conducting wire determines its resistance to the passage of a current of electricity. That is to say, the thicker the wire the less will be its resistance. A wire of a certain cross-sectional area will have twice the resistance of a wire of twice this area.

Just as greater force is required to send water through a long pipe than is required to send it through a shorter one, so greater pressure is required to send electricity through a long conductor than through a short one. A wire three miles long has three times the resistance of a similar wire only one mile in length.

Again, if two wires are taken of the same length and cross-sectional area but of different materials, they are found to have a different resistance. The resistance of a unit cube of any material is called its specific resistance.

We can sum up the above observations as follows :—

1. Resistance is inversely proportional to cross-sectional area.
2. Resistance is directly proportional to length.
3. Resistance is directly proportional to the specific resistance.

Therefore resistance equals specific resistance multiplied by length divided by cross-sectional area, or, where R represents resistance, l represents length, a represents cross-sectional area, and ρ represents specific resistance—

$$R = \rho \times \frac{l}{a}$$

ρ is a Greek letter pronounced " rho."

As wires have a circular cross-sectional area, and the diameter may be known but not the area, the formula for the calculation of the area of a circle may be given—

$$\text{Area} = \frac{\pi \text{ diameter}^2}{4} = \cdot 7854 \times \text{diameter}^2$$

since π (pronounced " pie "), which is the ratio between the circumference and diameter of a circle, equals 3·1416.

The C.G.S. Units.—Most electrical measurements are made in the C.G.S., or centimetre, gramme, second system, in preference to the foot, pound, second units, as the metric system is so much easier than the English system for calculation purposes. Therefore, in speaking of the resistance of a unit cube of a metal as being the specific resistance of that metal, we refer to a cube measuring one centimetre along each of its edges.

Arrangement of Resistances.—If a current passes through several resistances in succession, as in Fig. 16, the resistances are said to be joined in series.

If the current divides at a certain point and passes through

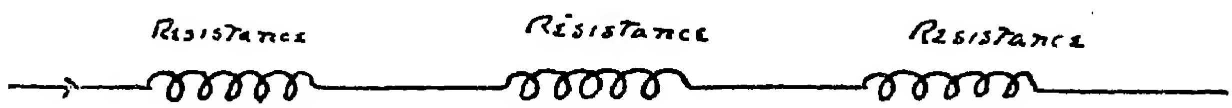


FIG. 16.—Resistances in Series.

resistances in such a manner that the different portions reunite at another part of the circuit, as in Fig. 17, they are said to be joined in parallel.

The adding of resistances in series is equivalent to increasing the length of the conductor so that the total resistance is equal to the sum of the separate resistances.

When resistances are arranged in parallel, however, several paths being offered for the passage of the current, it is equivalent to increasing the cross-sectional area of the original conductor. The current passing through the separate resistances is proportional to the conductivity of each path.

The conductivity of a conductor is the reciprocal of its resistance—that is to say, it is equal to one divided by the resistance in ohms.

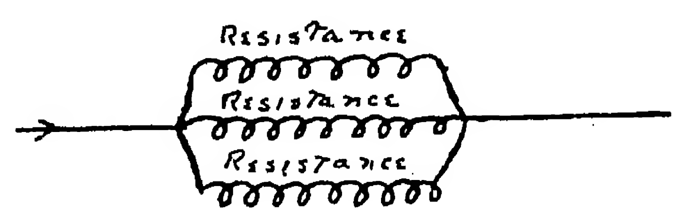


FIG. 17.—Resistances in Parallel.

We can say, therefore, that the amount of current passing through different resistances joined in parallel is proportional to the reciprocals of the resistances, and that the total resistance of resistances in parallel is equal to the reciprocal of the sum of the reciprocals of the separate resistances.

Now, if we take a circuit in which it is desired to find the current flowing at a given E.M.F., it is necessary to take into account the total resistance of every part of the circuit. If the source of supply be a primary cell, the *internal resistance* of the cell must be reckoned with. This varies in different types of cell, and depends on—

1. The resistance of the elements, depending on the material and size.
2. The resistance of the electrolyte, depending on the material and the distance between the plates.

Arrangement of Cells.—When two or more cells are joined together in order to produce greater effects, the arrangement is called a battery. The cells, like the resistances mentioned, may be arranged in either series or parallel.

To join cells in series, the negative pole of one cell must be connected to the positive of the next, and so on, as in Fig. 18. To join them in parallel all the negative poles must be connected and all the positives, as in Fig. 19.

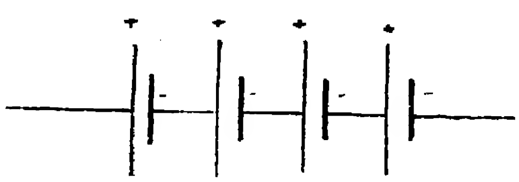


FIG. 18.—Cells in Series.

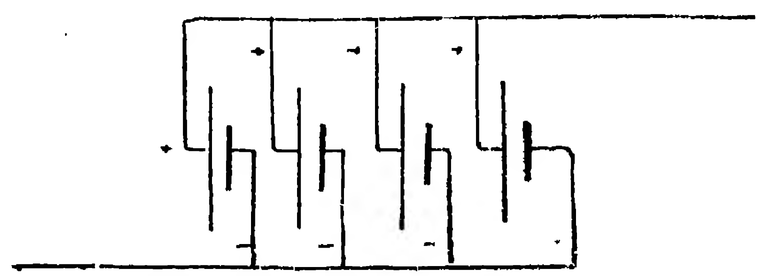


FIG. 19.—Cells in Parallel.

A combination of these two arrangements may be taken, known either as a parallel-series or a series-parallel arrangement. Such an arrangement is shown in Fig. 20.

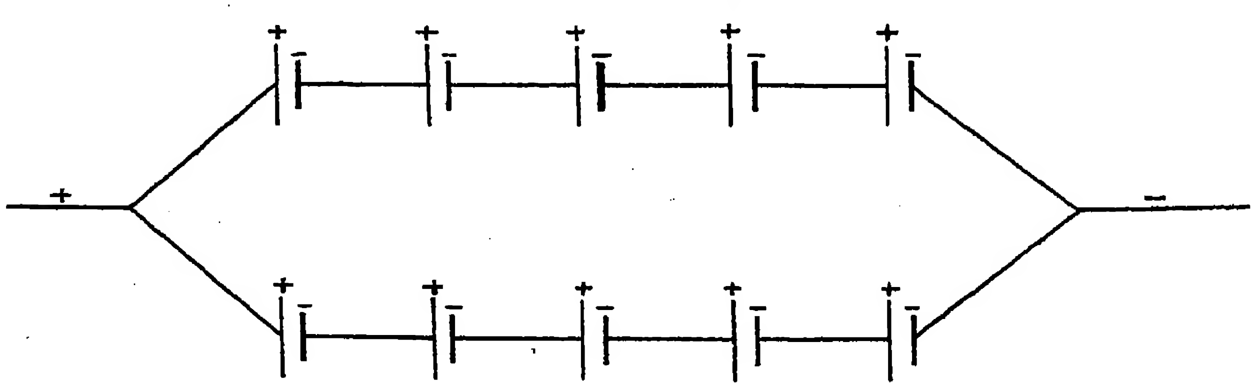


FIG. 20.—Series-Parallel or Multiple Arc Arrangement of Cells.

As is seen in the figures, it is usual to represent the positive pole of a cell by means of a long thin line, and the negative by means of a shorter and thicker one.

When a number of cells are joined in series, the total pressure or E.M.F. is equal to the sum of the individual E.M.F.'s, and the total internal resistance of the battery is equal to the sum of the individual internal resistances.

In a parallel arrangement of the cells, provided that they are all of the same type, the total E.M.F. is equal to the E.M.F. of one cell, and the total internal resistance is equal to the

internal resistance of one cell divided by the number of cells in parallel.

A series arrangement is made when greater pressure is desired, and a parallel arrangement when current is the chief object. The latter arrangement is often referred to as being connected in "multiple arc."

We are now in a position to elaborate the previously given simple mathematical expression of Ohm's Law in order to provide full equations for the calculation of the quantities in more complicated circuits.

Thus if R represents the total external resistance in a circuit, r represents the internal resistance of each cell employed, E represents the E.M.F. of each cell, n represents the number of cells used in series, and p represents the number of cells or rows of cells in parallel, it will be easily seen that the following equations hold good for the three different arrangements :—

Series— $$C = \frac{nE}{R + nr}$$

Parallel— $$C = \frac{E}{R + \frac{r}{p}}$$

Series-Parallel— $$C = \frac{nE}{R + \frac{nr}{p}}$$

Maximum Current from Battery.—A little consideration of Ohm's Law shows us that we obtain the maximum amount of current from a given number of cells when the external resistance is equal to the internal resistance of the battery.

Let N equal the number of cells.
n equal the number of cells in series.
p equal the number of groups in parallel.
r equal the internal resistance of each cell.
E equal the E.M.F. of each cell.
R equal the external resistance.

Obviously np equals N.

It is required to prove that to obtain the maximum current we must arrange the cells so that

$$R = \frac{nr}{p} \text{ (total internal resistance)}$$

As stated above— $$C = \frac{nE}{R + \frac{nr}{p}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From which we obtain the following :—

$$C = \frac{npE}{Rp + nr} \quad \dots\dots\dots\dots\dots\dots (2)$$

But $$np = N \quad \dots\dots\dots\dots\dots\dots (3)$$

By substituting in equation (2)

$$C = \frac{NE}{Rp + nr} \quad \dots\dots\dots\dots\dots\dots (4)$$

Now NE is a constant. That is to say, its value cannot be changed without altering the total number of cells. Therefore in order that the expression in equation (4) may have a maximum value the denominator $(Rp + nr)$ must be a minimum.

In order to find the condition when this denominator is a minimum we must first square both sides of equation (4), giving us

$$C^2 = \frac{N^2E^2}{(Rp + nr)^2} \quad \dots\dots\dots\dots\dots\dots (5)$$

Now $$(Rp + nr)^2 = (Rp - nr)^2 + 4Rpnr$$

Substituting this value in equation (5) we get

$$C^2 = \frac{N^2E^2}{(Rp - nr)^2 + 4Rpnr} \quad \dots\dots\dots\dots (6)$$

Now $(Rp - nr)^2$ must always possess a positive value, being a perfect square, and therefore in order that the denominator in equation (6) may be as small as possible $(Rp - nr)^2$ must be equal to zero, which is when

$$Rp - nr = 0$$

or

$$R = \frac{nr}{p}$$

When we have a number of cells at our disposal and we desire to find out the arrangement which will give us the maximum amount of current through a circuit of known external resistance, the following formula can be used, using the same lettering as before :—

$$n = \sqrt{\frac{NR}{r}}$$

or to express the relationship in words, the number of cells in series is equal to the square root of the product of the total number of cells and the external resistance divided by the internal resistance of one cell.

The proof of the correctness of this formula is as follows. As previously proved

$$R \text{ must equal } \frac{nr}{p} \quad \ldots\ldots\ldots\ldots\ldots(7)$$

But $N = np$, therefore $p = \frac{N}{n}$

Substituting in equation (7) we get

$$R = \frac{nr}{\frac{N}{n}} = \frac{n^2r}{N}$$

or

$$n^2 = \frac{RN}{r}$$

therefore

$$n = \sqrt{\frac{RN}{r}}$$

Now n equals the number of cells to be used in series, and it only remains to divide the total number of cells by this figure to obtain the number of parallel groups.

In practice it will be found that the figures arrived at by this method of calculation are very seldom whole numbers. As it is impossible to have a fraction of a cell, however, it is necessary to make the arrangement most nearly approaching the result of the calculations. It is necessary, of course, that there should be an equal number of cells in each series group, otherwise we should have one group forcing a current through another on account of the unequal E.M.F.'s which would be set up, a state of affairs which must very carefully be avoided when using cells in parallel, as it would result in the running down of one lot, and cause serious deterioration.

Potential Slope.—So far we have only considered Ohm's Law with respect to the whole length of any circuit. It holds good, however, for any portion of a circuit, and consequently, provided that we know the resistance between any two points, we can easily calculate the difference of potential between these two points.

Let us take a simple case for example. We will assume that the cell in the accompanying figure (Fig. 21) has an E.M.F. on open circuit of two volts and an internal resistance of two ohms. If we connect up to the external circuit *R*, which we will consider to have a resistance of two ohms, from Ohm's Law we have

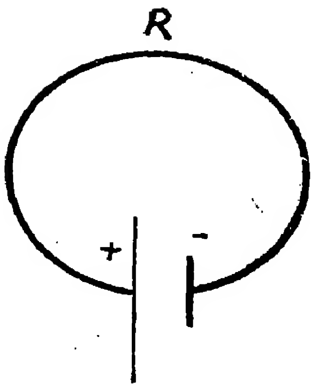


FIG. 21.—Simple Circuit.

$$C = \frac{2}{2+2} = \frac{1}{2}$$

that is to say, a current of half an ampère is flowing in the circuit. Now let us take that portion of the circuit consisting of the cell alone and again apply the law.

If $\quad C = \frac{E}{R}$, $E = C \times R$, therefore $E = \frac{1}{2} \times 2 = 1$

which tells us that on the closed circuit the difference of potential between the two poles of the cell has fallen to one volt, or that a pressure of 2—1 volts has been taken up to force a current of half an ampère through the internal resistance of the cell. If the difference of potential be calculated through the external portion of the circuit in a similar way it will also be found to be one volt.

If the resistance of the external portion of the circuit be great in comparison with the internal resistance the latter can be neglected, as its introduction into the denominator will only make a very slight difference in the final result of our calculation.

Let us consider a circuit of the following type (Fig. 22). The external resistance between A and B is 20 ohms. The E.M.F. of the battery shall be taken to be of such a quantity as to produce a difference of potential between A and B of ten volts. Now if the wire be of uniform size between A and B, according to the laws of resistance half the wire will have half the resistance of the whole, therefore the resistance between A and C (which latter point we will take to be equidistant between A and B) will be 10 ohms. Applying Ohm's Law the difference of potential between A and C is found to be 5 volts.

A very simple method of finding the difference of potential between any two points of the wire AB is as follows. From A

draw a line AE perpendicular to AB and allow its full length to represent 10 volts. Now divide it into ten equal parts. Each part will represent 1 volt. From E draw a line to B.

The line EB is known as the potential slope. It affords us a means of quickly finding out the difference of potential between, say, the two points F and G. Proceed as follows.

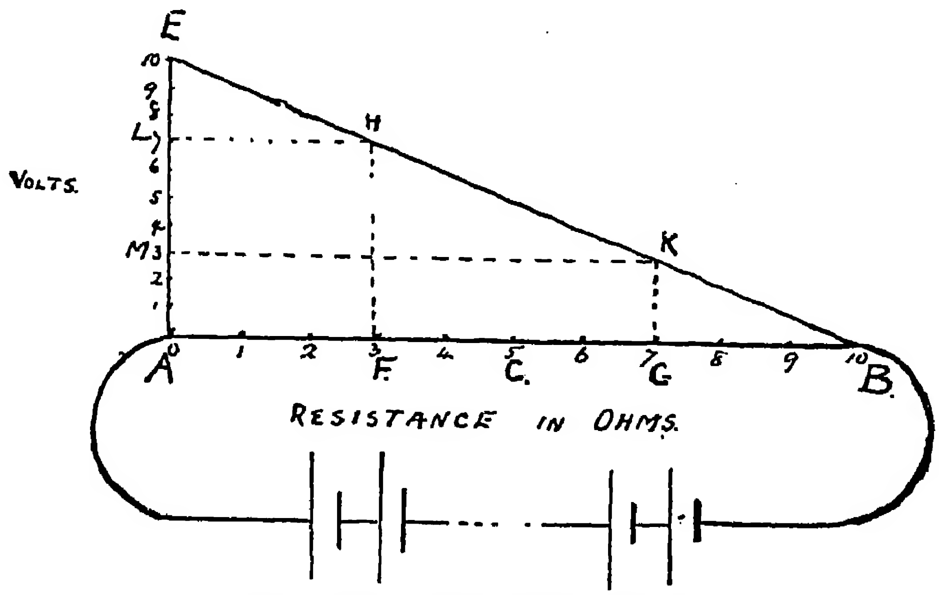
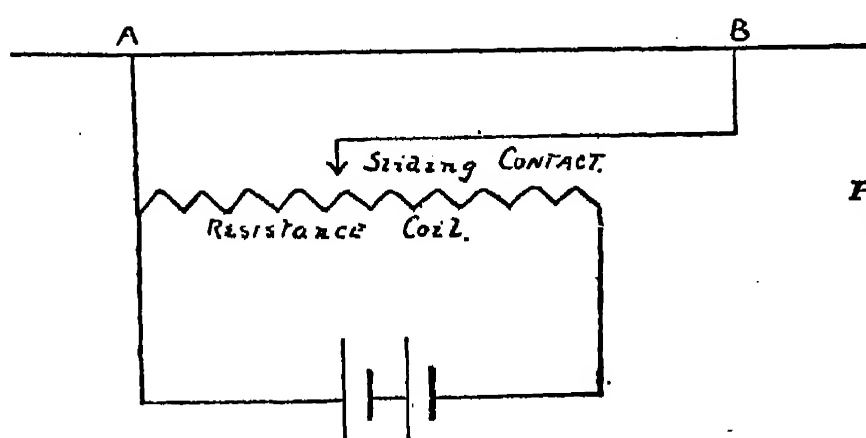


FIG. 22.—Potential Slope.

From F and G draw two perpendiculars FH and GK. From H and K draw the lines HL and KM perpendicularly to the line AE. Then the length of the line LM will give the difference of potential between F and G.

The Potentiometer.—Although the necessity of using the above method for calculating drop of potential may never



Potentiometer for varying P.D. between A and B.

FIG. 23.—Potentiometer.

arise during the work of a wireless operator, it will enable him to better understand the working of an instrument called

a potentiometer, which is used in a type of receiver to be described later. This is an instrument used for varying the difference of potential between two certain points at will, and consists of a resistance wire permanently fixed across a source of supply, from which tappings can be taken, one usually being fixed and the other variable, by means of a sliding contact as in the preceding figure (Fig. 23).

CHAPTER V.

MAGNETISM.

Lodestone—Magnetism—Artificial magnets—First law of magnetism—Magnetic induction—Theory of Magnetism—Lines of force—Attraction and repulsion—Permeability—Magnetic field—Terrestrial magnetism.

BEFORE we can properly study certain other qualities which must be considered in applying current electricity to wireless telegraphy, it is necessary to know something about magnetism.

Lodestone.—In certain parts of the world—notably Norway, Sweden, and parts of America—a peculiar type of iron ore is found. One of the properties of this mineral is that if a piece of it be suspended so that it is free to turn in a horizontal plane it invariably takes up a position pointing north and south. The ancients utilised this property of the ore as a means of guiding their ships across wide tracts of ocean, and for this reason it became known as leading-stone, or lodestone. Originally the mineral was found mostly in Magnesia, in Asia Minor, and it is from this source that such words as magnet, magnetism, magnetic, etc., have been derived. Lodestone has the power of imparting this property of magnetism to certain other substances.

Artificial Magnets.—If a piece of hard steel be stroked continuously in the same direction with a piece of lodestone, after a while it will be found that the steel possesses similar evidences of magnetisation. If suspended by means of a thread, it will be found to always point in a northerly and southerly direction. It will be found to possess the power of picking up pieces of iron or steel, and if it be plunged into a quantity of iron filings and withdrawn it will be seen that the filings have adhered to it, particularly at two well-defined points. These points are known as the poles of the magnet, and are

called the north-seeking and south-seeking poles, or simply the north and south poles respectively.

The First Law of Magnetism.—If two such steel magnets be taken and one of them be suspended, on bringing the second one near it in various ways, the following effects are produced.

On approaching the north pole of the suspended magnet with the north pole of the other, the former swings round in a direction which places its north pole as far away as possible from the approaching north pole of the second magnet.

A similar effect is produced when the south pole of the free magnet is made to approach the south pole of the suspended magnet. When the north pole of the free magnet is brought towards the south pole of the suspended magnet the latter is found to swing so that it comes to rest in a position as near as possible to the approaching north pole.

From these facts we see that—

1. Like poles repel each other.
2. Unlike poles attract each other.

Of course, although the north-seeking pole is usually termed the north pole, it is in reality a south pole, and the south-seeking pole is really a north pole. This will be readily understood when it is remembered that unlike poles attract.

Magnetic Induction.—If a steel magnet be taken and a piece of iron be placed in contact with it or in close proximity to it, this piece of iron is found to possess magnetic properties, and it can be proved that the end of the iron nearest the pole of the magnet possesses opposite polarity to that pole.

It is said that magnetism has been induced in this piece of iron. If the magnetising influence be removed, by either taking away the magnet or the piece of iron, the latter will be found to contain no remaining trace of magnetism, or at least very little.

On performing the same experiment with a piece of hard steel, however, it is found that it retains a certain amount of magnetism even after the magnetising force has been removed. This magnetism is called residual magnetism, and it is found that the harder the steel used the greater is the amount of this residual magnetism.

Under the heading " Artificial Magnets " it was stated that a piece of hard steel could be magnetised by stroking with a

magnet. If the same experiment is tried with a piece of soft iron no or very little permanent magnetisation results.

Theory of Magnetism.—When a steel magnet is subjected to blows from a hammer it is found to lose its magnetism. When a piece of steel which is undergoing the process of magnetisation is tapped with a hammer in a certain way the magnetisation is accelerated.

When a magnet is heated to a red heat it loses its magnetic properties.

When a very long magnet, say a magnetised knitting-needle, is broken up into a great number of small parts, each part is found to be a complete magnet in itself.

All these facts agree with the theory that has been put forward in explanation of magnetism. It is thought that all

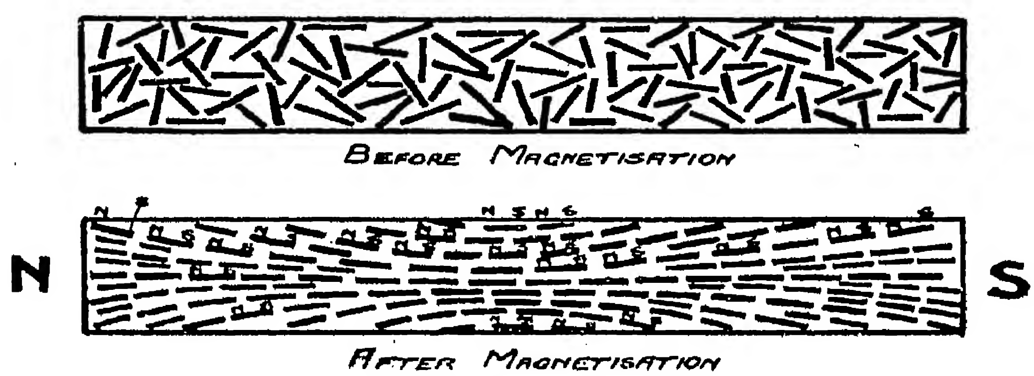


Fig. 24.—Arrangements of Molecules before and after Magnetisation.

the molecules in a magnetic substance are complete permanent magnets. Under ordinary circumstances these infinitely small, permanent magnets are lying in a haphazard fashion in all sorts of directions, so that the effect of an equal number of north and south poles is to neutralise the total forces.

Under the influence of some strong magnetising agent, however, the molecules are rearranged so that they are lying in symmetrical lines throughout the length of the magnetic substance in such a manner that the unlike poles of each adjacent molecule are together. The accompanying diagram will help to explain this idea (Fig. 24).

It will be seen from this theory that it is impossible to have a magnet with only one pole.

This theory is quite consistent with the behaviour of steel and soft iron under magnetising influences, for it can be readily understood why hard steel, in which the molecules are more

closely packed than in soft iron, takes a longer time for the rearrangement to take place. At the same time, once this rearrangement has been accomplished it requires a correspondingly great force to place the molecules in their original state of chaotic disorder, thus explaining why hard steel retains its magnetic properties indefinitely.

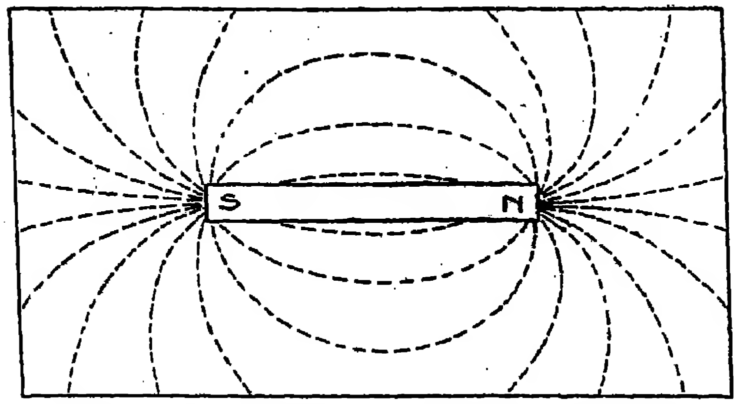


FIG. 25.—Magnetic Field round Bar Magnet.

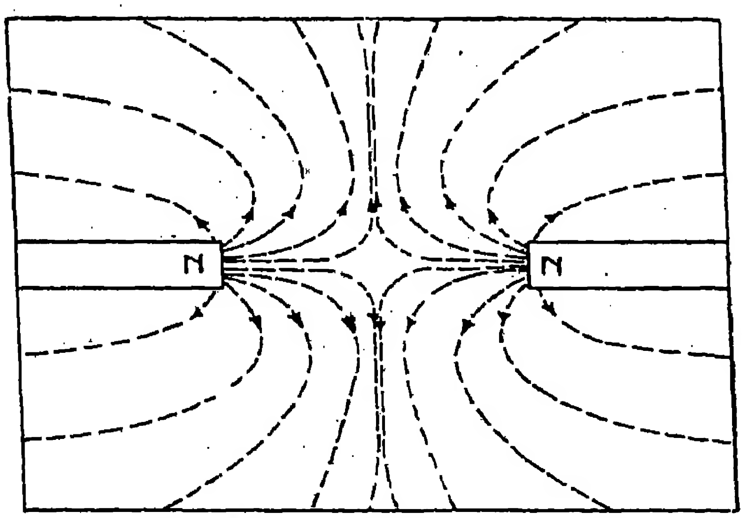


FIG. 26.—Magnetic Field between Like Poles.

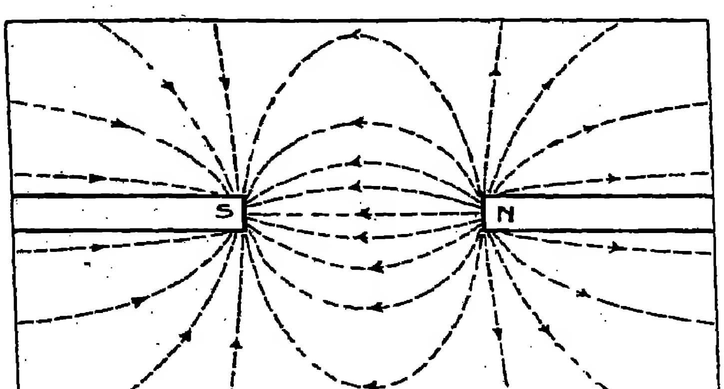


FIG. 27.—Magnetic Field between Unlike Poles.

Lines of Force.—As a magnet has the power of inducing magnetism in a neighbouring piece of iron, its force must be exerted at a distance, and we can easily find in what manner this force is distributed round a magnet.

Let us take an ordinary bar magnet and lay over it a sheet of stout paper. If then a pepper-box filled with fine iron filings be used to sprinkle the filings over the paper, each separate filing, under the influence of the magnet, becomes a small magnet, and the filings arrange themselves with unlike poles together along certain lines closed upon the ends of the bar magnet. as in Fig. 25. We thus see that the force or a magnet appears to be along these lines defined by the filings, and consequently these lines are called lines of force.

By taking different combinations of magnets we can use the filings to demonstrate the effect of one magnet upon another, and so on. For instance, Fig. 26 shows the lines from two like poles being diverted into a plane at right angles to the length of the magnets, and this behaviour indicates the repulsive force which exists between the two like poles.

In the next diagram Fig. 27, the unlike poles of two bar magnets are adjacent to each other, and the lines appear to

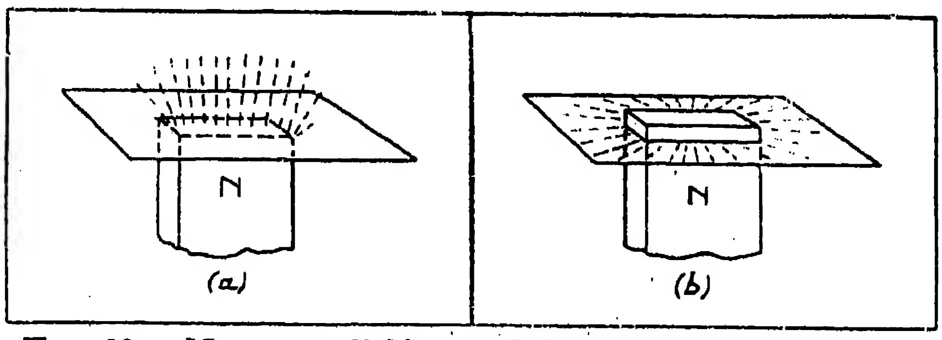


FIG. 28.—Magnetic Field round One Pole of Magnet.

stream across from pole to pole. They may be likened to stretched elastic threads which tend to shorten and draw the two poles nearer together. Thus unlike poles attract one another. In order to show that the lines of force do not exist only in one plane, but that they pass through the medium surrounding a magnet in all directions, the experiments shown in Fig. 28 (*a*) and (*b*) may be made. In Fig. 28 (*a*) the filings erect themselves when the paper is held over the end of one pole of the magnet; and in Fig. 28 (*b*) where the paper is slipped over the end, the filings radiate from the pole in the plane of the paper which is at right angles to the length of the magnet.

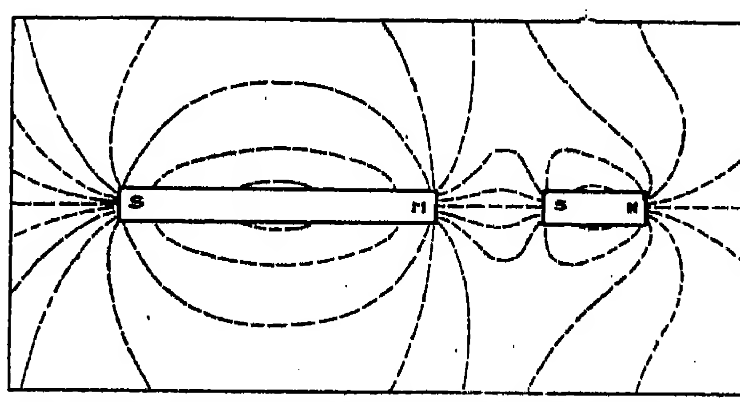


FIG. 29.—Distortion of Field due to Soft Iron.

Again, if we take a bar magnet with a piece of iron near one of its poles we find the distribution of the lines of force very much as shown in Fig. 29. The lines of force appear to be bent over from their original position as though the piece of iron offers an easier path, or, in other words, as though the

piece of iron has the power to concentrate the lines of force through a smaller space.

Permeability.—The property possessed by magnetic substances of concentrating the lines of force is known as permeability. It is found that soft iron has much greater permeability than steel, by which we mean that it has a much greater concentrating effect on the lines of force than steel.

As the magnetising force increases, so does the permeability up to a certain point ; it then commences to decrease. This implies, that after a certain strength of magnetising force has been reached, any further increase will not result in any large increase of the number of lines passing through the iron. The latter is then said to be in a state of magnetic saturation.

Magnetic Field.—The whole medium which is permeated or occupied by magnetic lines of force is called a magnetic field. Magnetic fields are compared one with another in terms of their intensity. A magnetic field of unit strength is one in which only one line of force exists per unit area. That is to say, that if a plane at right angles to the direction of the lines of force be taken and divided up into squares measuring one centimetre each way, in a field of unit intensity only one line of force would pass through each square. Thus, if, say, ten lines of force exist per unit area the field is said to be more intense than one in which less than ten lines exist.

Terrestrial Magnetism.—The earth behaves as if it is a huge magnet. It has a north and a south magnetic pole, between which poles exist lines of force similarly disposed as in the case of a bar magnet.

A compass needle or any suspended magnet always sets itself along these lines of force.

The magnetic poles are situated at some distance from the geographical poles, and from London the north magnetic pole is some 16¼ degrees to the west of the true north. This angle is called the angle of declination, and is found to vary from year to year.

If a magnet be suspended in such a manner that it can swing in a vertical plane, even though it be perfectly balanced before being magnetised, it is found to incline towards the north pole. The angle of inclination is called the angle of dip, and at the north magnetic pole the needle is found to point straight downwards.

In diagrams illustrating magnets and the lines of force

set up by them, it is usual to fix arrow-heads to the lines. This does not indicate a flow along these lines, but merely shows the direction of the force exerted.

The force is always exerted in a direction from the north pole to the south pole outside the magnet, and from the south pole to the north pole inside the magnet, and is therefore the direction in which a little north pole would move if placed on the line of force outside the magnet.

CHAPTER VI.

ELECTRO-MAGNETS.

Deflection of magnet by current—Ampère's rule—Multiplier or galvanometer—Electro-magnetic field—Maxwell's corkscrew rule—Solenoid—Electro-magnets—Ampère-turns — Electro-magnetic induction—Induction coil.

WE must now bring our attention back to a statement made in the first chapter, where it was mentioned that the wire connecting the two poles of a simple cell possesses peculiar properties. A magnetic needle in the vicinity of such a wire carrying a current is affected in a definite manner.

If the magnetic needle be placed directly over a wire in such a manner that its axis is parallel to the wire and a current be forced through the latter, the needle is found to deflect.

The direction of this deflection depends on the direction of the current through the wire and on the position of the poles of the needle.

Ampère's Rule.—The famous scientist whose name has been given to the unit of current, formulated a rule by which the relation between the deflection and the direction of the current can be very easily remembered.

If a man were to swim along a wire in the direction of the current-flow, facing the needle, and with his hands outstretched, the north pole of the needle will always turn to his left hand.

If now a wire be taken of such a shape that after the current through it has passed in one direction over a magnetic needle it can pass in the directly opposite direction under the needle, whatever the power producing this deflection may be, it should now have a greater effect. For, applying Ampère's rule, the swimmer would now be on his back and his left hand would be in the same direction as that already taken by the north pole of the needle.

"*Galvanometer*."—If then we take a coil of wire, wound as in the accompanying diagram (Fig. 30), a small current produces a sufficiently accumulated effect, after passing through the many turns, to cause a considerable deflection of the needle.

This arrangement is often called a "multiplier," and is used largely to detect the presence of a current. When used for this purpose it is made up into a convenient form and called a "galvanometer." More will be said on this subject later. Just as a magnet has been shown to have the power of inducing magnetism in a piece of iron at a distance from it, so a current passing through a wire has this power.

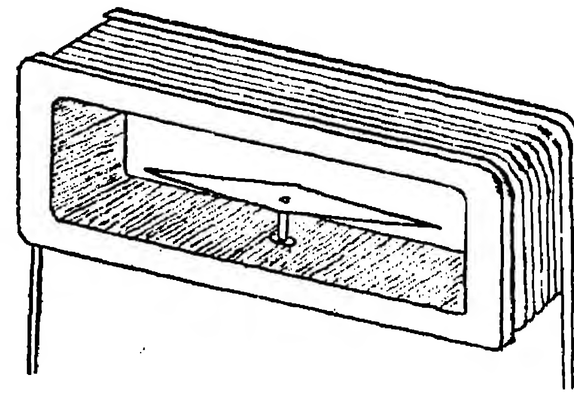


FIG. 30.—"Multiplier" or "Galvanometer."

A very simple experiment sufficiently demonstrates the fact that magnetic lines of force are set up by the passage of a current. In Fig. 31, a wire is shown passed vertically through a sheet of stiff paper. If a current be now forced through the wire, and iron filings be scattered over the paper, they are

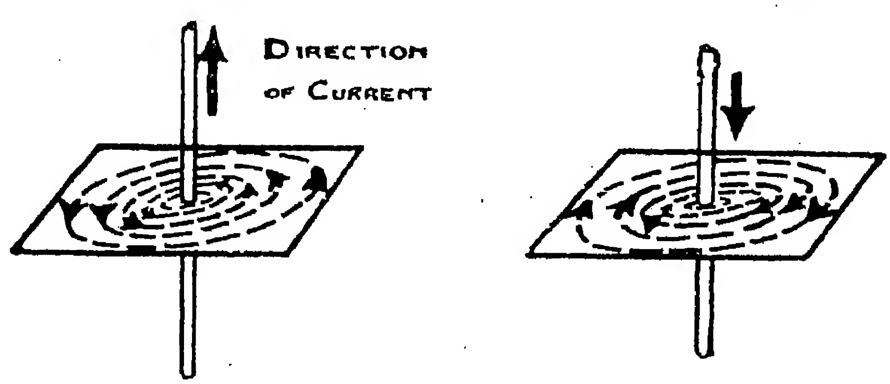


FIG. 31.—Magnetic Field round Current-carrying Wire.

found to take up a position in the form of concentric circles with the wire as a centre. It is found that if the current be increased the influence over the iron filings is more strongly marked, and that if it be decreased the opposite effect is produced.

Each of the iron filings whilst under the influence of the current possesses the properties of a small magnet, and if the polarity of these magnets be examined it is found to depend

upon the direction of the current. The figure shows the corresponding polarity or direction of strain along the lines of force for the two directions of current along the wire.

A rule, known as *Maxwell's Corkscrew Rule,* provides an easy method of remembering the relative directions of current and lines of force. If we screw a corkscrew in the direction of the flow of current the corkscrew rotates in the direction of the magnetic lines.

The Solenoid.—If a piece of wire be wound in the form of a helix, as in Fig. 32, and a current be passed through it, it is found to act in the same manner as a bar magnet. Such an arrangement is called a solenoid, and it is seen by applying the law just given that the lines of force produced around each adjacent turn of wire will give resultant lines of force passing through the centre or axis of the coil. If this arrangement be suspended so that it can swing in a horizontal plane, it will take up a position pointing north and south. The polarity of course is decided by the direction in which the current is passing through the wire.

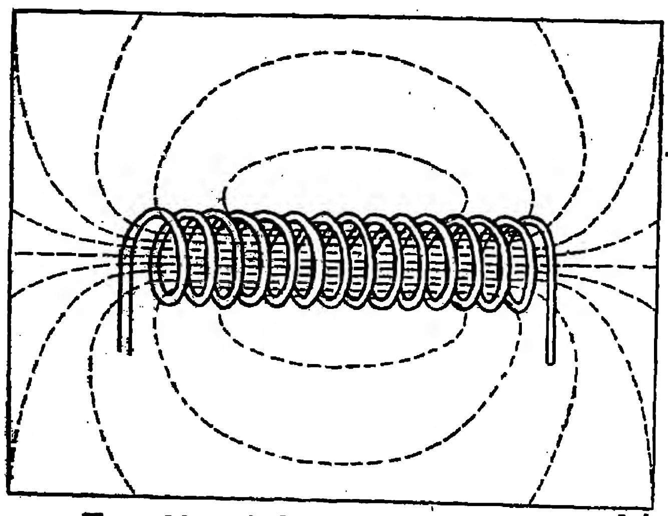


FIG. 32.—Solenoid and "Field."

Electro-Magnets.—Now let us take a single turn of wire round the edge of a thin disc of iron and cut the whole arrangement in two along a diameter of the disc. We should then have a sectional view as shown in Fig. 33.

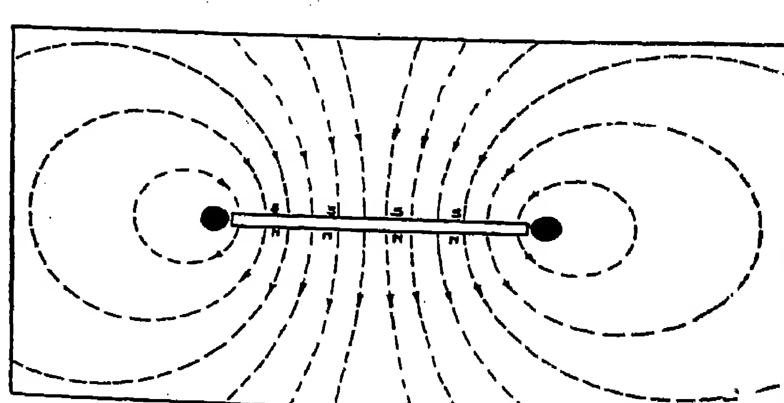


FIG. 33.—Theory of Electro-Magnet.

Imagine that it is possible for us to pass a current through this half-turn of wire and let us examine the effect. The lines of force set up in the form of concentric circles round the wire

cut through the iron disc, and in doing so convert each part into a small magnet, so that the disc becomes a bundle of very small magnets all lying with their north or south poles uppermost, according to the direction of the current. If now we take a great number of similar arrangements we should have the equivalent of a bar of iron wrapped round with a coil of wire (Fig. 34), and we should have the small magnets lying in a similar position to that taken up by the molecules of the bar magnet, as explained under the heading, "Theory of Magnetisation."

A bar or rod of iron round which is wound a coil of wire conveying a current is called an electro-magnet.

Now, in a previous chapter it has been explained that the permeability of iron enables it to concentrate lines of force. It will be easily seen, therefore, that we have here a means of producing a very powerful magnet.

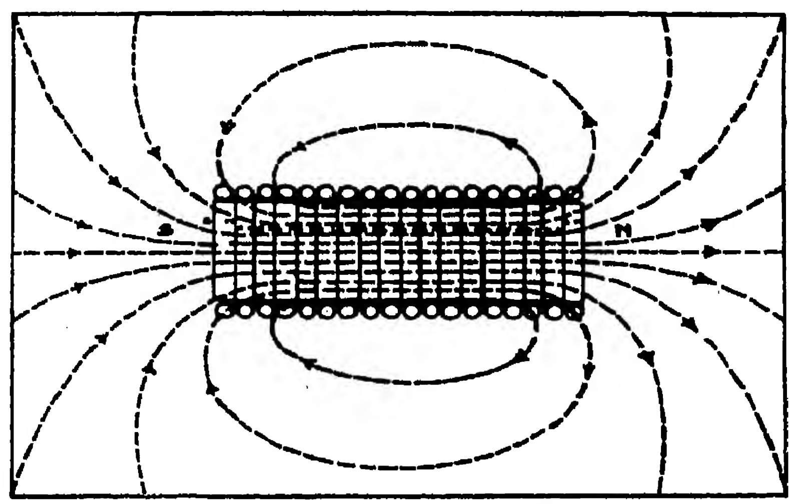


FIG. 34.—Electro-Magnet.

As was explained a little way back, the intensity or strength of a magnetic field depends upon the strength of the current producing it. In the case under consideration, therefore, any increase in the current will produce a corresponding increase in the magnetism of the iron bar. Again, if we increase the number of turns of wire round the bar we have a greater number of lines of force passing through it.

We can say, then, that the strength of an electro-magnet depends on the number of ampères flowing and upon the number of times these ampères pass round it, or, as it is more usually expressed, the strength depends on the ampère-turns.

If a piece of steel be used instead of a piece of iron, after the current has been cut off it is found to retain some of the magnetism. A piece of soft iron, however, loses almost all its magnetism, and use is made of this fact in the designing of many pieces of wireless apparatus. At the same time the magnetic effect produced in a piece of soft iron is greatly in

excess of that produced in a piece of steel with the same ampère-turns on account of the higher permeability of soft iron. In the designing of an electro-magnet account must be taken of the saturation point, for after a certain increase in the number of turns used with a certain current has been reached, any further increase would be waste.

Electro-Magnetic Induction.—It has already been shown that a magnetic field is set up round a conductor through which a current is passing. Faraday discovered that the inverse of this action can take place, and that when magnetic lines of force cut a conductor or vary in such a manner that the number of lines cutting the conductor is changed, an E.M.F. is induced in that conductor.

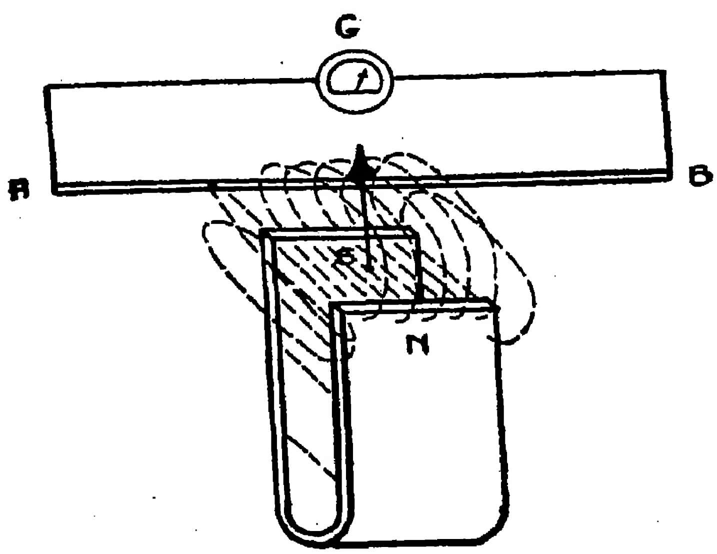


FIG. 35.—Induction.

Let AB represent a conductor to the ends of which a sensitive galvanometer, G, is connected (Fig. 35). If the horseshoe magnet, NS, be brought quickly towards the conductor, as shown by the arrow, a deflection of the needle of the galvanometer takes place, which denotes that a current has been set up in AB. The needle is found to return immediately to its original position when the magnet comes to rest, thus showing that the current set up is only of a momentary nature.

If the magnet be rapidly withdrawn a second deflection of the needle takes place, this time in the opposite direction, and this also is only of a momentary nature.

During the motion of the magnet the lines of force cut through the conductor in varying number. The nearer the magnet is brought the greater is the number of lines of force cutting through AB, and in accordance with the above law a current of varying value is set up. When the magnet has come to rest, the lines of force being stationary, no further induced effect is produced, and the momentary nature of the current is explained. When the magnet is removed the number of lines cutting through AB is rapidly lessened

and a current is once more induced, but in the opposite direction to the first.

Now if the time occupied in moving the magnet towards the conductor be varied we find the following effect. The quicker the movement the greater is the induced E.M.F. Thus, if the movement were to take place in one second, we should find an E.M.F. ten times the strength of that which would be produced if the movement occupied ten seconds.

This is expressed in the following important law :—The value of the induced E.M.F. is directly proportional to the rate at which the magnetic lines cut the conductor.

Now it is readily seen that the same effect is produced when the magnet is kept stationary and the conductor moved, and it is on this principle that the machine called the dynamo is constructed.

The Induction Coil.—If both conductor and magnet remain stationary, but the magnetic field alone is removed,—by using, for instance, an electro-magnet instead of a permanent magnet in Fig. 35, and breaking the current circuit,—then again a transient E.M.F. will be set up in the conductor. If the conductor be given the form of a coil of a great number of turns the effect is greatly increased. The effect depends on the rate at which the number of lines of force linked with the conductor varies, and if each line of force passes through a great number of turns it is linked with the circuit a corresponding number of times. Thus in Fig. 36 the thick line represents the conductor and the thin one a line of force linked with it. If the conductor be given three turns instead of two, one of the ends must be bent round and threaded through the closed line of force again. Thus we see that where two linkages existed before three linkages now exist. If then a magnetic field suddenly grows or dies away along the axis of a coil of wire of a great number of turns, the rate of change of the number of linkages is enormous and the induced E.M.F. great. Fig. 37 shows such an arrangement. P is the winding of an electro-magnet supplied with current from a battery, B, S is a solenoid

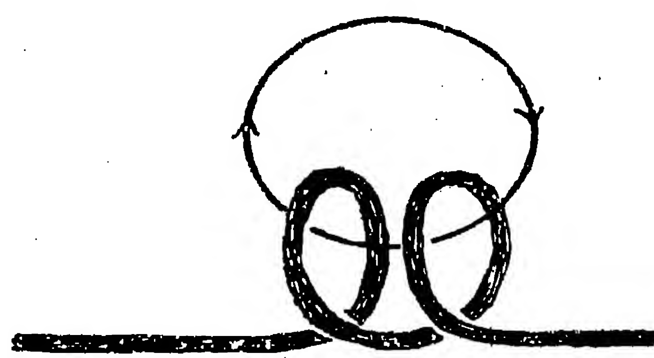


FIG. 36.—Linkage of Line of Force.

consisting of a great number of turns of insulated wire. When the circuit is closed by means of the key, K, the lines of force set up by the magnet pass through the coil, S, and induce in it a momentary current. The momentary nature of this current is indicated by a kick of the galvanometer needle, G, and is due to the fact that the current very soon reaches a constant strength and the number of linkages of lines of force ceases to vary. If the circuit be interrupted, a second induced E.M.F. is created in the opposite direction. It is found that the ratio between the induced E.M.F. and the E.M.F. of the first current is approximately the same as that between the number of turns in the conductor and the number of turns round the electro-magnet. An arrangement of this sort, used in connection with some means of very rapidly making and breaking the circuit containing the electro-magnet winding and battery, is called an induction coil. A more detailed account of an actual coil will be given later.

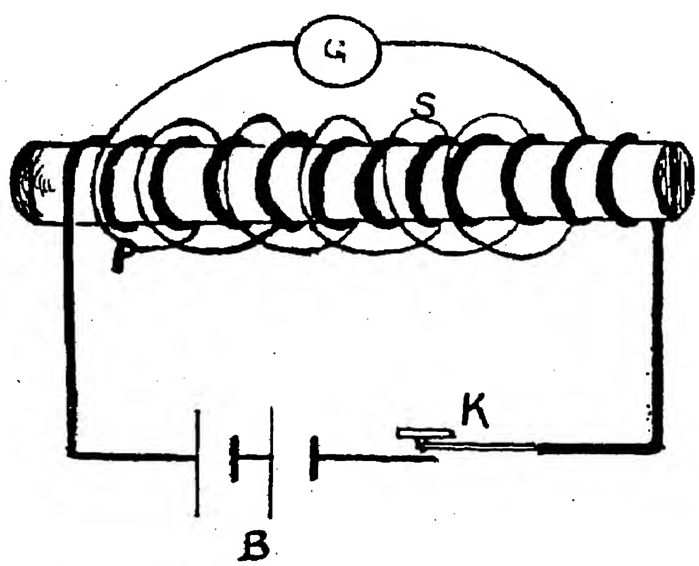


FIG. 37.—Principle of Induction Coil.

The electro-magnet winding is called the primary, and the conductor winding the secondary.

CHAPTER VII.

DYNAMO, MOTOR, ROTARY CONVERTER.

Fleming's rule—Current in conductor moving through magnetic field—Alternating current—Sine curve, construction of—Absoissa—Ordinate — Commutator — Brushes — Pulsating current —Armature—Core — Field magnets — Dynamo—Motor—Back E.M.F.—Use of machines either as motor or dynamo—Speed of motor—Field regulator—Starter—No load release—Overload release—Rotary converter—Slip rings—Periodicity—Transformer.

THE DYNAMO.—If we take a coil of wire so arranged that it is capable of being rotated in a magnetic field, according to Faraday's law given in the preceding chapter, we should expect an E.M.F. to be set up in it during rotation, as it would be continuously cutting through the lines of force.

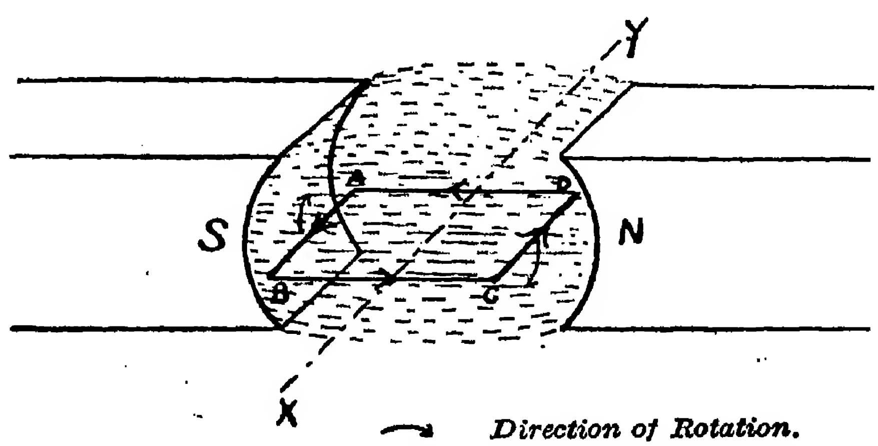


FIG. 38.—Rotation of Conductor in Magnetic Field.

The direction of this induced E.M.F. would vary according to the polarity of the magnets producing the field and according to the direction of rotation. In Fig. 38, N and S are the poles of two magnets. ABCD is a coil of wire capable of rotation on a horizontal axis XY, which is at right angles to

the direction of the lines of force, shown as dotted lines between N and S.

Fleming's Rule.—Before discussing the effect produced by rotation it is necessary that Fleming's rule showing the relationship between motion, magnetism, and induced E.M.F. should be given.

Place the thumb, the first, and middle fingers of the right hand, at right angles to each other as in Fig. 39, then, if the thumb points in the direction of motion, and the first finger in the direction of the magnetic lines, the middle finger will point in the direction of the induced E.M.F. If the left hand be used the law is applicable for determining the direction of rotation of a motor. This may be remembered by thinking of "thu*M*b" as representing *M*otion, and "*F*orefinger" as representing *F*ield. Applying this simple rule to Fig. 38, we readily see that the direction of the induced E.M.F. in ABCD, when moving in the direction shown, is as indicated by the arrow-heads, for the lines of force in the field are from the north pole to the south pole, as explained on page 43.

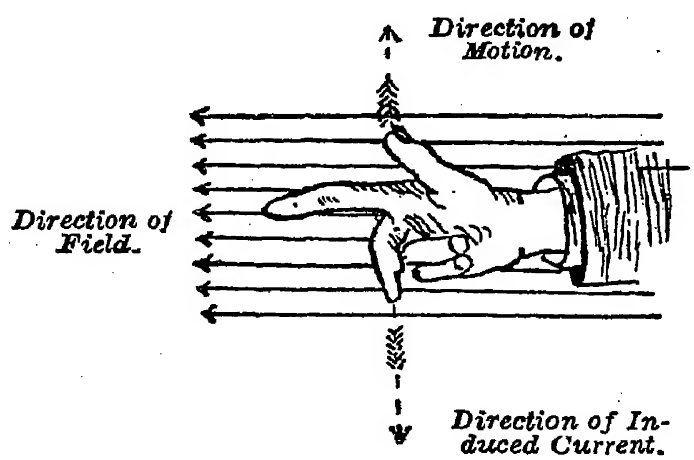


FIG. 39.—Fleming's Rule.

As the portion AB is moving upwards against the lines near the south pole, the portion CD is moving downwards through the lines near the north pole, thus the E.M.F.'s produced tend to force a current through the conductor in one direction.

The current only lasts in this direction until the part AB is vertically above CD.

After this position has been passed an application of the rule given shows that the current now induced in AB is in the reverse direction, and that it continues in this direction until CD is vertically above AB.

A little reflection shows that the strength of this current as well as its direction varies.

When the portions marked AB and CD are moving through the upper and lower parts of the circle of rotation, it is seen that for a short time they are practically moving in a direction

parallel to that of the lines of force, and consequently as the rate of cutting is so very slow, the induced E.M.F. is correspondingly small. As a matter of fact, when the two parts are vertically one above the other there is no induced E.M.F., or, as it is usually stated, the E.M.F. has a zero value.

The rate of cutting gradually increases until the two parts AB and CD are exactly opposite the centres of the magnetic poles. It is obvious that this is the case, as the conductor at this stage of its rotation is cutting the lines at right angles. At this point, therefore, we find a maximum induced E.M.F. The value of the E.M.F. then gradually decreases until the two parts are once more vertically one above the other, this time the part that was formerly uppermost occupying the lower position.

In Fig. 40 the sections of the parts AB and CD of the moving conductor shown in Fig. 38 are represented by the points A and B. If the conductor be moved at a uniform speed it will pass into the positions shown at A_1B_1, A_2B_2, and A_3B_3 in equal periods of time, as the angle between any two adjacent positions is 30°.

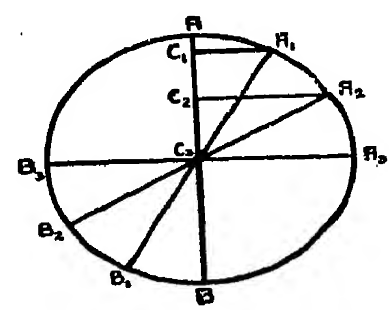


FIG. 40.—Diagram illustrating Variation of Rate at which Lines of Force are cut.

In passing from AB to A_1B_1 the number of lines of force cut is proportional to the length of the line AC_1. During the next two periods of 30° the cutting of lines is proportional to the lengths of the lines C_1C_2 and C_2C_3, and it will be seen that these lengths gradually increase through the first quarter revolution.

Thus, to summarise the action, we find that during one-half of a revolution an E.M.F. is induced in the conductor which starts from a zero value, gradually rises to a maximum value, and again gradually falls back to a zero value.

During the next half-revolution a similar rise and fall of E.M.F. takes place, which is, however—as previously pointed out—in the opposite direction.

Now the current resulting from such an E.M.F. is known as an alternating current, and such a current can be graphically represented by what is known as a sine curve.

Sine Curve.—Curve drawing, or curve plotting, as it is usually called, provides a method of showing graphically

the relationship existing between different dimensions. Thus if we can represent a certain relationship by such an equation as

$$X = Y + 2$$

we see that the value of X depends on the value of Y, or that if Y increases in value X also naturally increases and vice versa.

The relationship between X and Y for varying values of each can be shown by means of a line as follows. Take a sheet of paper on which a number of straight lines are ruled dividing it up into a number of equal squares. Now the side of one of these squares in a horizontal direction

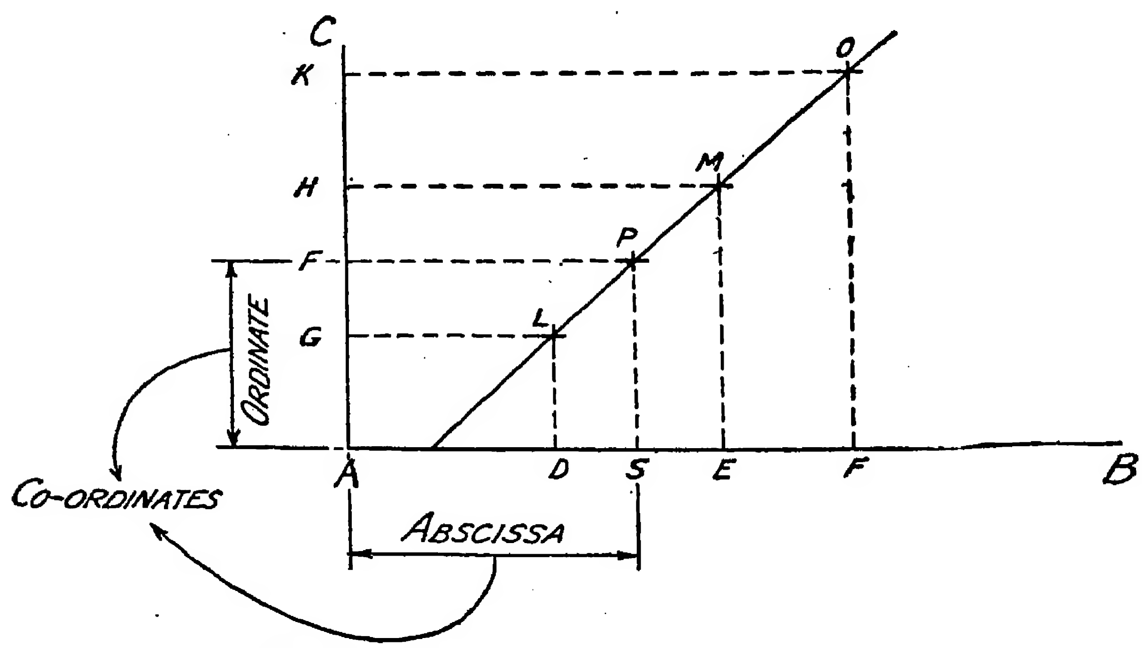


FIG. 41.—Example of Curve Plotting.

can represent a unit or fraction of a unit of the type required to measure X, and the side of one of the squares in a vertical direction can represent a unit or fraction of a unit of the type required to measure Y. Let us then draw a horizontal line AB (Fig. 41) sufficiently long to represent the maximum value of, say, X. Then AA (which is zero) would represent a zero value of X and AB the maximum. From A draw a line AC sufficiently long to represent a maximum value of Y. Then AA would again represent a zero value of Y in this case, and AC the maximum.

Now let us take the points D, E, and F, along AB representing different values of X. Substituting these values in our equation $X=Y+2$ we can calculate the corresponding values of Y. Make the points G, H, and K, represent these

values along the line AC. Now if we draw lines from D, E, and F, at right angles to AB, and also draw lines from G, H, and K, at right angles to AC, these lines will intersect at the points L, M, and O. Through A, L, M, and O, draw a line. This line is the curve representing the relationship between X and Y. Although the line may be a straight one it is still called a curve, and such a straight line would indicate that X varied uniformly as Y. In the curve described only positive values have been taken for X and Y. If, however, it is desirable to represent negative or minus values for these two quantities, the lines AB and AC require to be continued in the opposite directions, namely, from A horizontally to the left, and from A vertically downwards.

If any point P be taken on the curve, projections from this point on AB and AC would give the respective values of X and Y represented by such a point. Suppose such projections be the points S and T, then AS and AT are called the co-ordinates of the point P. AS is called the "abscissa," and AT is called the "ordinate." Now let us consider the appearance of a curve showing the relationship existing between the induced E.M.F. and time, which is the factor determining the position of the conductor with respect to the poles of the magnets. Taking a piece of squared paper as above, the squares along AB represent equal periods of time. The squares along AC represent equal values of E.M.F.

Now, commencing with the conductor at rest in such a position that AB is vertically above CD (Fig. 38), the state of affairs can be represented by the point A as the time is zero and the induced E.M.F. is zero. During the lapse of the amount of time represented by one of the squares along AB a certain number of lines of force have been cut by the moving conductor and an E.M.F. has been set up. The value of this E.M.F. is then measured along AC and the point P found as described above. As time passes the E.M.F. increases up to a maximum point P_1, after which it again falls until CD is vertically above AB (Fig. 38). It will be seen that the curve will take the appearance shown in the first half of Fig. 42. Because the current now commences to pass in an opposite direction, the measurements for the finding of the various points on our curve are now taken below the line. By the time the part AB once more reaches its original

position vertically over CD the curve has once more returned to the horizontal line AB.

We thus see that the E.M.F. follows a curve as in Fig. 42 during one complete revolution of the conductor. Such a curve represents what is known as one complete cycle of alternating current.

This form of curve is called a sine curve, and such a curve can be constructed as follows :—

With the point A as centre on a line AB, describe a circle of radius AC (Fig. 42). Divide the circumference of the

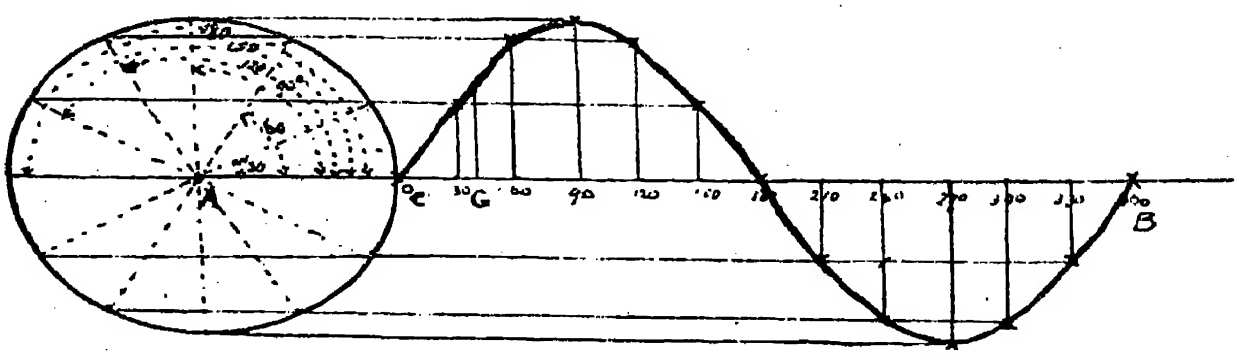


FIG. 42.—Sine Curve.

circle and the line CB into the same number of equal parts, say twelve. From the points on the circumference of the circle draw horizontal lines and from the points on the line CB draw vertical lines. Numbering the lines as shown, a curve may be drawn through the points of intersection of the correspondingly numbered lines.

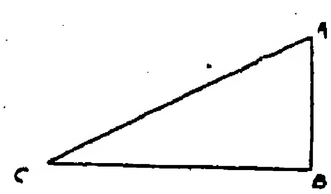


FIG. 43.—Explanation of the Term "Sine."

Now if we take a right-angled triangle ABC, as shown in Fig. 43, the ratio of AB to AC is called the sine of the angle ACB. That is to say—

$$\frac{AB}{AC} = \text{sine } ACB$$

Turning back then to Fig. 42 we see that if CB represents 360 degrees, and if the maximum ordinate or radius of the circle be called unity, any ordinate FG is proportional to the sine of the angle represented by its abscissa CG. An alternating current which is represented by such a sine curve is called a simple harmonic or periodic current.

Commutation.—Let us now take our attention back to

Fig. 38. If the conductor ABCD be cut between C and B and the two ends joined to two half-rings of copper mounted on a cylinder of insulating material, as in Fig. 44, we find that the current forced through an external circuit connected to two carbon or copper brushes, so fixed that each one is in contact with the copper ring at diametrically opposite points, is no longer of an alternating type.

In the accompanying diagram it will be seen that although the current in the conductor is still alternating as before,

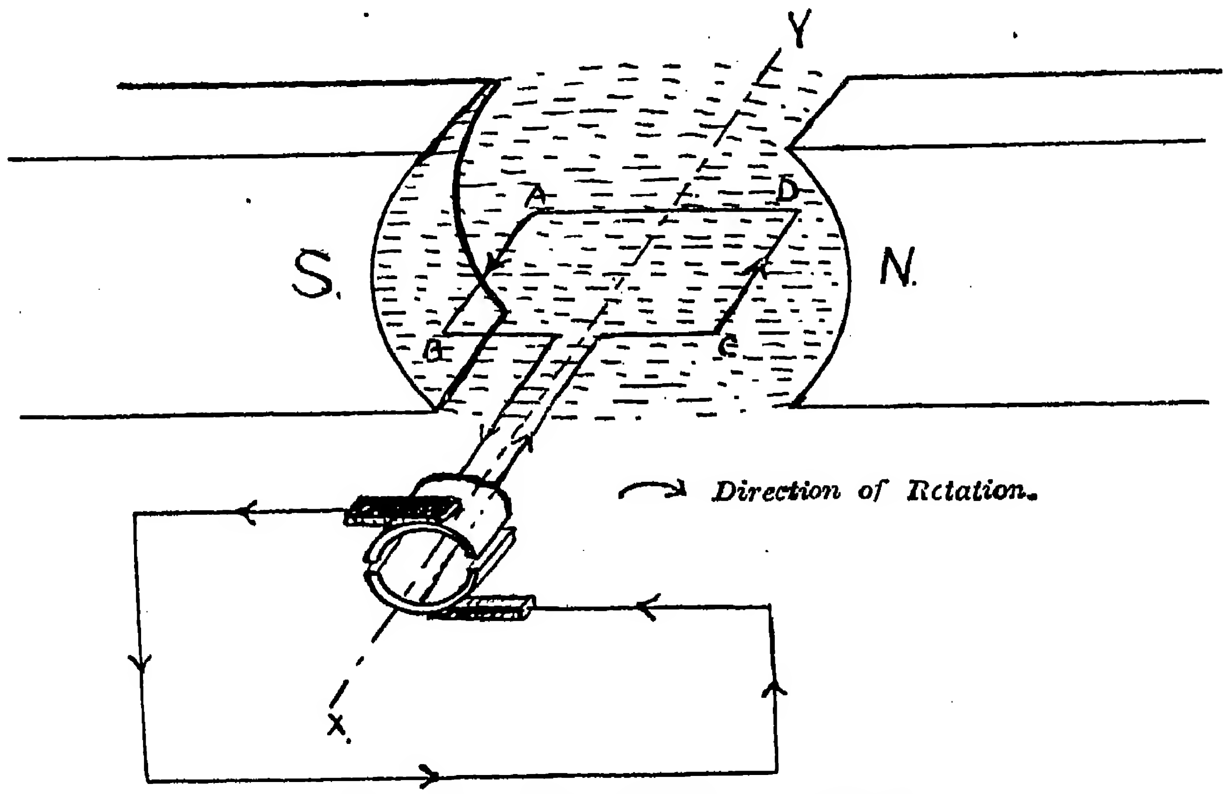


FIG. 44.—Use of "Commutator."

the ends of the external circuit alternately make connection with each end of the conductor, so that the current through the external circuit is continuously passing in the direction shown by the arrow-head.

Because this arrangement of two copper half-rings on an insulating cylinder commutes or changes the alternating current induced in the conductor into a continuous or direct current in an external circuit, it is called a *commutator*.

Although this external current is called a direct or continuous current it still fluctuates in value, rising from zero to a maximum and so on as before. The curve of this current,

however, differs from that of the alternating current in that each half is above the horizontal line, as in Fig. 45.

Now let us consider what affects the induced E.M.F.

Let N equal the total number of lines of force between the magnet poles, and n equal the number of revolutions per second of the conductor. Then—

The time taken for one revolution equals

$$\frac{1}{n} \text{ second.}$$

The time for one half-revolution equals

$$\frac{1}{2n} \text{ second.}$$

The mean rate at which the part AB of the conductor

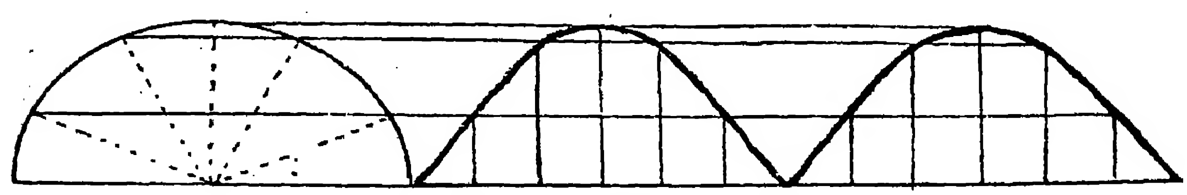


FIG. 45.—Curve of Pulsating Current.

cuts the lines of force is therefore the number of lines cut divided by the time taken in seconds per half-revolution, or—

$$\text{mean rate} = \frac{N}{\frac{1}{2n}} = 2nN \text{ lines per second.}$$

In the ordinary way of reckoning, when a conductor cuts lines of force at the rate of one hundred million per second, an E.M.F. of 1 volt is induced.

100,000,000 is usually written 10^8.

Therefore an E.M.F. of $\frac{2nN}{10^8}$ is set up in the part AB of the conductor under consideration. An equal E.M.F. is set up in the part CD; thus, adding the two together, we see that during one half-revolution the mean induced E.M.F. is $\frac{4nN}{10^8}$.

It can now be seen that any increase in the value of either n or N will give a greater value of induced E.M.F. Now it has been previously shown how iron has the power of concentrating a magnetic field. If, therefore, the conductor ABCD be wound round a piece of iron of such a size that it almost takes up all the space between the poles of the magnets N and S, the field through which the conductor has to pass is greatly intensified.

Development of Armature.—In actual practice the iron round which the conductor is wound is of a cylindrical shape, with slots all round the periphery. If a solid piece of iron of this type is rapidly rotated through a magnetic field it acts as a circuit of one turn and *eddy currents* are set up in it which tend to produce heat and waste energy. In order to prevent these eddy currents the iron "core," as it is called, is built up of thin sheets or laminations of iron all clamped together in the required form.

Now the rotation of one coil of wire even on such an iron core would not produce a very large current, and the current which it would produce would be of too pulsating a nature (as seen by the curve).

If we use several coils of wire, however, suitably disposed round the core and connected to a corresponding number of commutator pieces, we can increase the induced E.M.F., and at the same time so tone down the pulsating nature of the current as to make it to all intents and purposes a current of constant E.M.F. The connections for a four-coil and four-part commutator arrangement are shown in Fig. 46. Starting from the point a, and following the winding round without reference at first to the commutator, it is seen that the coils form a closed circuit and are electrically in series with one another in the order of the numbers marked on them. As regards the connections to the four segments, w, x, y, and z, of the commutator, it is seen that at two of these, x and y, the pressures in the windings are both directed from (at x), or both directed towards (at y), the junction with the connecting wire. At the other two, z and w, one pressure is towards the junction, and the other directed from it. If, therefore, brushes be placed on x and y, they supply current to an external circuit, whilst for the moment z and w are idle bars. The development of the curve for the current produced in the external circuit can be seen in Fig. 47. The

two thin curves show the currents produced when the brushes are in contact with the two different pairs of commutator bars.

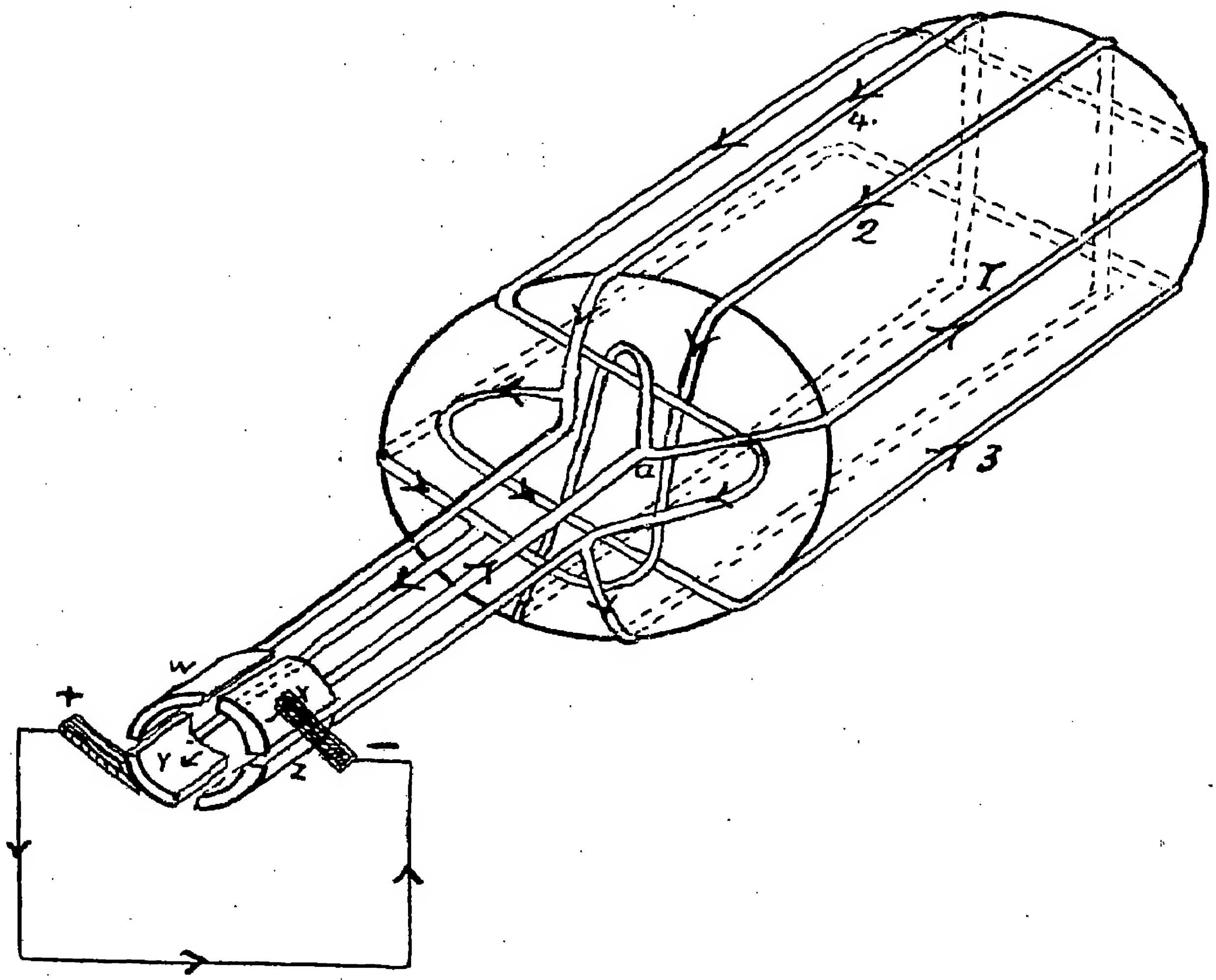


FIG. 46.—4-Coil Armature Winding Wire Connections.

The thick curve shows the resultant current, and it is seen that this current never reaches the zero value.

A machine capable of producing current on the principles

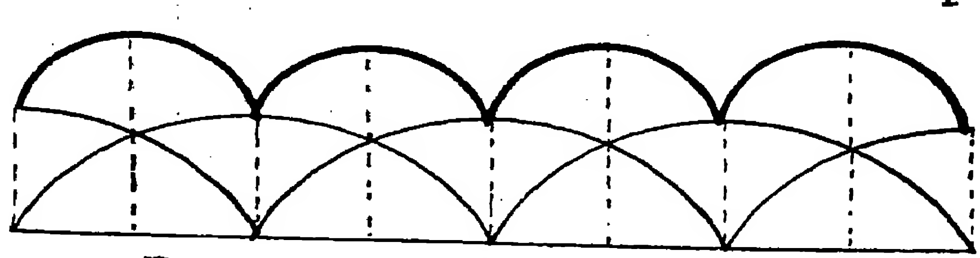


FIG. 47.—Development of D.C. Current.

explained above is called a *dynamo*. The moving portion, consisting of iron core, conductor windings, and commutator, is called the armature, and the fixed portion consists of the

framework of the machine and the magnets, which are called *field magnets*. The latter are never permanent magnets, as shown in the explanatory diagrams, but are invariably electro-magnets.

Armatures are wound in many different ways and are of different types. There are ring armatures, drum armatures (which are of the type described above), and open-coil armatures. The different ways of winding, such as lap winding, wave winding, etc., do not directly concern the wireless operator; and, in fact, it is very seldom that the care of a dynamo ever comes under his charge. There are, however, many text-books which give full and mathematical consideration to the subject, and consequently nothing further than the very elementary treatise already given will be dealt with here.

THE MOTOR.—Now, in a dynamo of large size capable of producing a large supply of electricity it is found that considerable power is required to turn the armature. This power is necessary to overcome the force that exists between the lines produced by the field magnets and those produced by the induced current in the armature.

If then, instead of turning the armature by means of mechanical power we pass a current through it, lines of force are produced due to the field current and due to the armature current, which lines of force have such an action, one set on the other, that the armature is caused to rotate.

Now, if we presume that the armature of the dynamo is driven in a clockwise direction, the force which the driving power has to overcome must be exerted in a counter-clockwise direction.

We thus see that if a current be sent through the field-magnet windings in the same original direction, and if a current be sent through the armature windings in the same direction as that taken by the induced current when using the machine as a dynamo, the armature will be forced to rotate in a counter-clockwise direction.

In the case of the machine being used to convert mechanical power into electrical power it has been called a dynamo. When electrical power is converted into mechanical power by such a machine the machine is called *a motor*.

When such a machine is being used as a motor it is readily seen that it can be acting as a dynamo at the same time. That is to say, because the armature is rotating through a

magnetic field an E.M.F. will be induced in the armature windings. But it has been stated that the armature is rotating in an opposite direction to the mechanical rotation produced when working as a dynamo, therefore the E.M.F. produced will be in the opposite direction to that produced when working as a dynamo.

Again, it has been stated that the E.M.F. used for driving

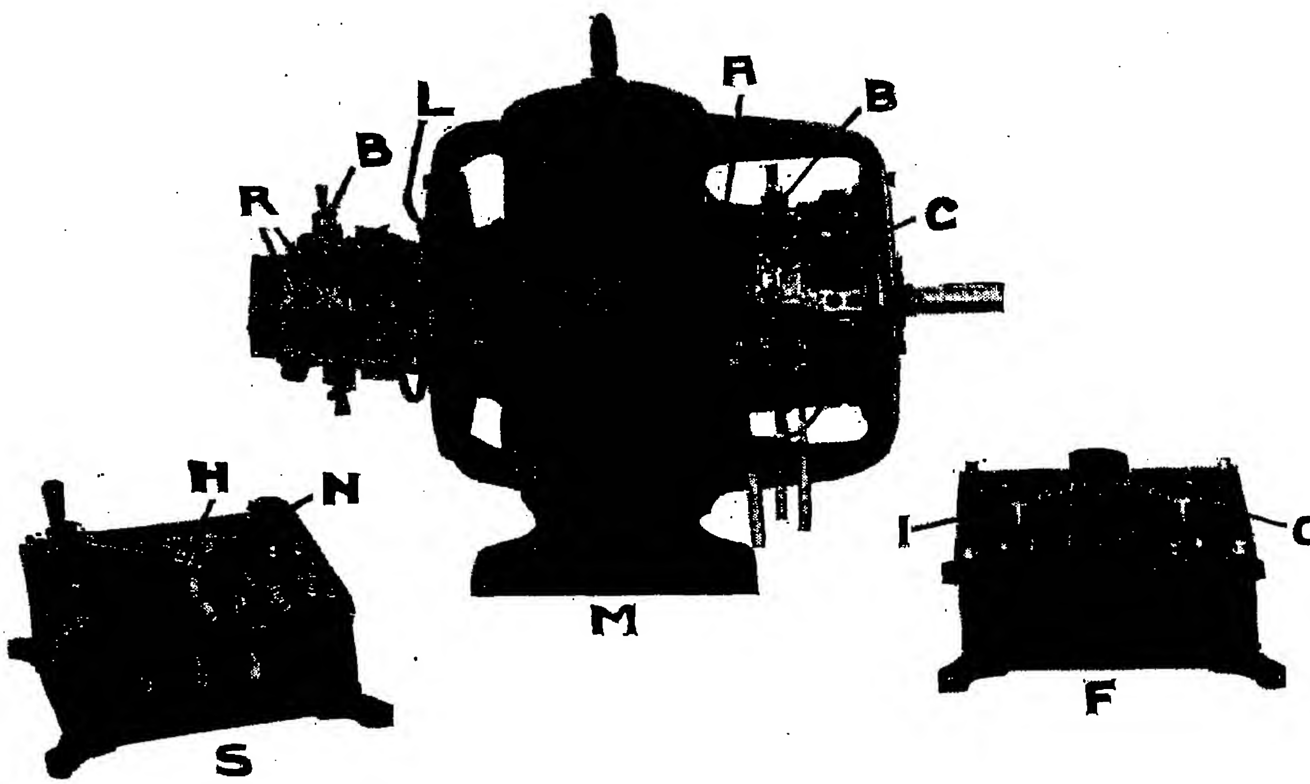


FIG. 48.—STANDARD 1½ K.W. ROTARY CONVERTER WITH STARTER AND FIELD REGULATOR.

A, Armature.—B, Brush Gear.—C, Commutator.—F, Field Regulator.—H, Boss of Starter Handle containing Spring.—I, Resistance "in" Stop.—L, Stauffer Lubricator.—M, Converter.—N, No-volt Release.—O, Resistance "out" Stop.—R, Slip Rings.—S, Starter.

the machine as a motor is in the same direction as that produced in the armature when the machine is used as a dynamo.

From these considerations we see that the E.M.F. produced by induction when the machine is acting as a motor is in the opposite direction to the E.M.F. of the current used to drive it as such.

The field windings and armature windings of motors and dynamos may be connected up in different ways. The field may be in series with the armature, it may be in shunt with

the armature; or a combination of these two arrangements may be used. In a motor used for wireless purposes the great desideratum is a constant speed under varying loads. The type most suitable for these conditions is the shunt-wound variety, and for this reason only this type will be described.

In the accompanying Fig. 49 it is seen how the field winding is in shunt with the armature winding. There is usually a certain amount of residual magnetism in the field magnets. When using the machine as a dynamo, and the armature is revolving, an E.M.F. is induced in it, this E.M.F. producing a current in the field coils, thus increasing the intensity of the field. This increase in field intensity causes a corresponding increase of induced armature E.M.F., which in turn once more still further increases the field current and the magnetic field. This process is continued up to a certain point, when, as previously explained, the cores of the field magnets become saturated and any further increase of field current produces no appreciable increase in field, and the building-up process therefore stops. At this point, unless the speed of the armature is increased, a maximum current is being delivered to the external circuit when it is closed. The value of the current passing through any part of the external circuit in accordance with Ohm's Law, depends on the resistance of the particular part, and on the terminal E.M.F.

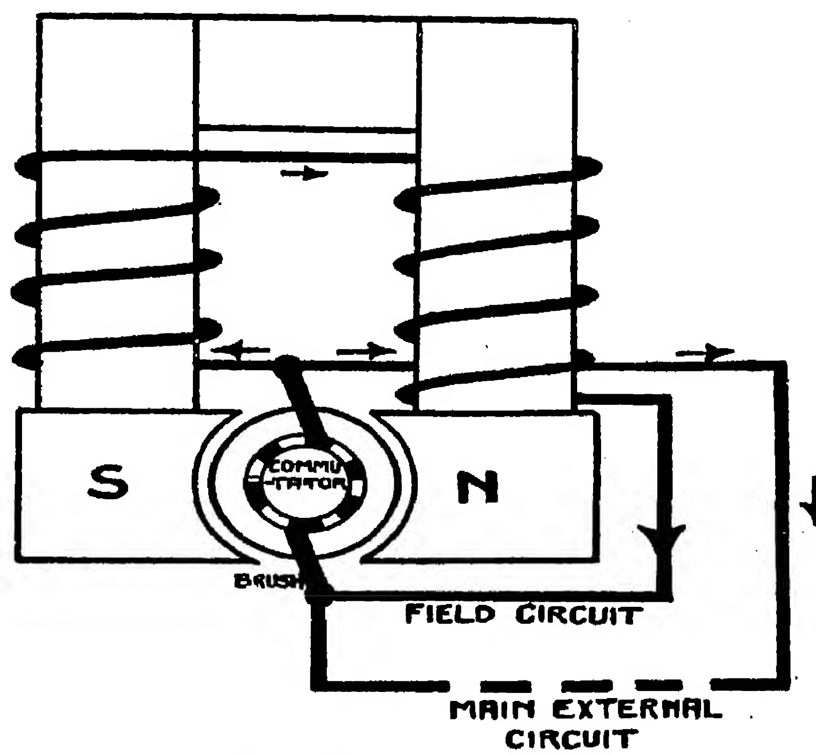


FIG. 49.—Shunt-wound Machine.

Because the current used in the field coils represents so much waste energy as far as the external circuit is concerned, care is taken in the designing of the machine to obtain the maximum effect with the smallest current. In the chapter

on electro-magnets it was shown that the amount of magnetism in an electro-magnet depends on the ampère turns. The energy loss is proportional to the square of the number of ampères, but is directly proportional to the turns—the resistance. Obviously it is most economical to use as many turns, and therefore as little current, as possible to obtain a given strength of field, in order to make the energy loss a minimum. The field magnets of a shunt-wound dynamo, therefore, are wound with a great number of turns of comparatively thin wire, and thus, the resistance being great, only a small portion of the induced current is taken from the armature to excite them, leaving the greater part for delivery to the external circuit.

The fact that the current passing through the coils of a

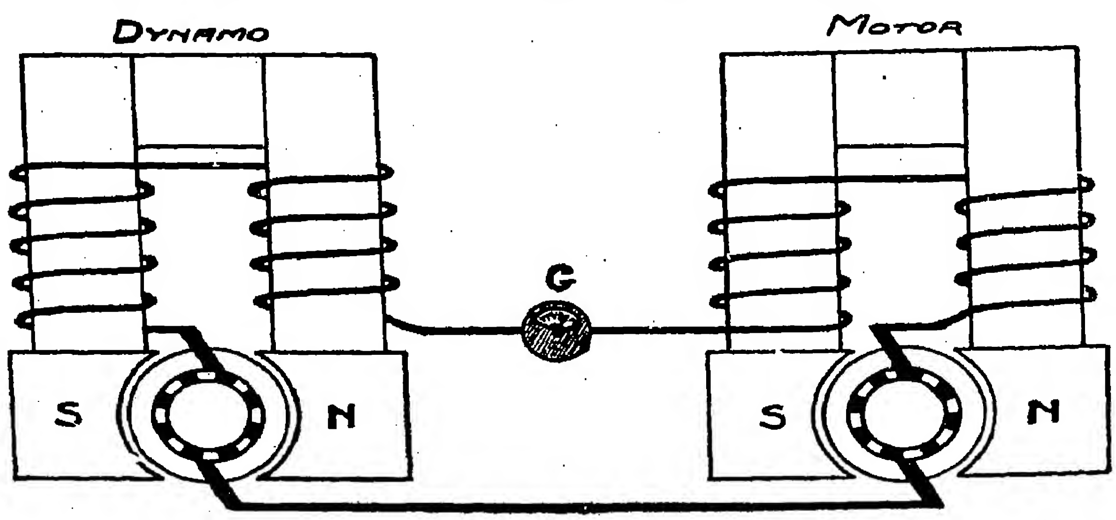


Fig. 50.—Similar Machines used as Dynamo and Motor respectively.

motor is opposed by a back E.M.F. may be tested experimentally.

In the accompanying Fig. 50 two machines of identical construction are shown, series-wound machines being taken to simplify the diagram. The one on the left is being driven as a dynamo by means of, say, a steam engine. This dynamo generates current, which is forced through the windings of the machine on the right. It will be seen that the direction of the current through the field windings in either machine is the same, but that the current through the dynamo armature is in the reverse direction to that through the motor armature. The latter will therefore rotate in the same direction as the dynamo is being driven. G represents a galvanometer in the circuit. The current through the motor causes the armature

to rotate, and a back E.M.F. is produced, as shown by a decrease in the deflection of the galvanometer needle. As the speed of the motor increases this deflection becomes gradually less and less, showing that the back E.M.F. is increasing. As the two machines are identical in construction it would be expected that when the speed of the motor has reached the same number of revolutions per second as that of the dynamo, the back E.M.F. would be equal to the E.M.F. produced by the dynamo. As a matter of fact this is impossible, as the friction, iron, and copper losses in the second machine have to be taken into account. Nevertheless, the gradually decreasing galvanometer deflection conclusively proves that a back E.M.F. is set up in the motor coils.

Just another illustration of the power of a machine, such as has been described, to act as a dynamo or as a motor, may be taken.

If a dynamo be used to charge a large battery of accumulators and the prime mover of the dynamo be cut off, the current then flows from the battery, and passing through the coils of the dynamo forces its armature to rotate still in the same direction.

Direction of Rotation.—A careful perusal of the foregoing experiments and diagrams shows that in a shunt motor as described, if the direction of the current through either the field coils or the armature coils be changed, the direction of rotation is changed; but if the direction of the current be reversed through both the field and the armature the two changes have an opposing effect and the armature still rotates in the same direction.

If a back E.M.F. is set up in a motor when rotating, it is obvious that the current passing through the armature must be controlled by the difference between this back pressure and the pressure applied. The actual value in ampères is obtained by dividing the excess pressure in volts by the resistance of the armature in ohms.

Now, wherever energy of one kind is used to produce energy of another kind there is bound to be some energy wasted in the form of friction, heat, etc. In the case of a motor, therefore, sufficient energy must be applied to overcome the amount of mechanical work to be done and to supply the power wasted in doing it.

Speed Regulation.—Now, a motor is self-regulating as regards the amount of power it uses. That is to say, the armature will rotate at the speed necessary to set up such a back E.M.F. that the amount of current controlled by the difference of pressure between the applied E.M.F. and this back E.M.F. is just sufficient to do the work required of the machine. It has been explained elsewhere that the amount of back E.M.F. depends on the rate of cutting lines of force; hence, if the magnetic field be an intense one the armature need only rotate at a slower speed to produce the required opposing pressure than would be necessary if the field were a weak one.

We have here, then, a means of regulating the speed of the motor. If a regulator consisting of a variable resistance be inserted between one of the supply mains and one end of the field magnet windings, the current passing through these windings can be regulated in such a way as to increase or decrease the intensity of the field produced, according to the conditions demanded by the work to be done.

If no mechanical work is being done by the motor—that is, if it is running free—the armature rotates at such a speed as to give a back pressure almost equal to the applied pressure, and consequently the current through the armature is only of a sufficiently small value to provide the energy wasted in the armature, etc., as heat and friction.

When mechanical energy is taken from the motor the speed is slightly reduced, and consequently the back E.M.F. is reduced, thus giving a greater difference between applied and back E.M.F., which is great enough to force the necessary increase in current through the armature corresponding to the extra driving power required.

The twisting force which makes the armature of a motor rotate is proportional to the strength of the magnetic field, and to the strength of the current passing through the conductors that are under the influence of the field.

As the strength of the field depends on the amount of current passing through the field coils, it is readily seen that to start a motor from a position of rest when most twisting force is required, it is necessary to force a large current through both the field and armature coils. Now the amount of current depends on the pressure, so that it is usual to apply the full available pressure to the field coils when starting.

In the case of the armature we must take another fact into consideration. When it is at rest there is no back E.M.F., and, consequently, if we were to apply the full available pressure to the armature the latter would be short-circuiting the source of supply of current. The current would then be sufficiently strong to injure seriously the windings, as great heat would be produced.

In order to avoid overheating the armature in this way, a resistance is usually inserted in the circuit through which the armature current is flowing, and the resistance is chosen of such a value that when the full available pressure is applied to this resistance in series with the armature, the strength of the current which flows is not much more than the strength

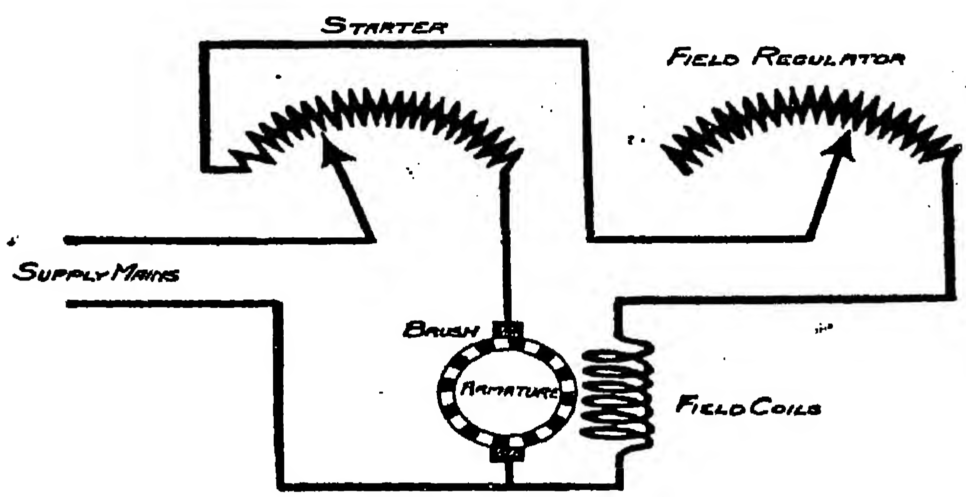


FIG. 51.—Theoretical Sketch of Motor Connections.

of current which flows when the motor is running and the full power is being taken out of it.

Starting Arrangements.—In order to understand the starting arrangements properly, a simple theoretical diagram of the connections is given (Fig. 51). One of the supply leads is connected to the moving arm of the starting resistance regulator. The end of the resistance first in contact with the moving arm is connected to one end of the field magnet winding, and the other end of the resistance is connected directly to one of the brushes resting on the commutator. A common lead is finally brought from the other end of the field magnet winding and the other commutator brush back to the return supply main. Where a field regulator is used, it is inserted between the end of the resistance first making contact with the moving arm and the first-mentioned end of

the field magnet windings, as in the diagram. Connections are made from different points of the resistance to brass studs, over which the end of the regulating handle moves.

When the arm of the starter is moved on to the first stud, the field current is a powerful one and the armature current is of a strength dependent on the resistance of the starting resistance together with the resistance of the armature as explained.

The armature now begins to turn until it has acquired a speed capable of producing a back E.M.F. as near the supply E.M.F. as the losses in the machine will permit. The armature current then falls to a minimum and the motor runs at a constant speed.

The handle is now moved over to the next stud, and because the current through the armature now increases, the motor speeds up until once more the back E.M.F. has increased to a maximum and the speed has become constant. This process is repeated until finally all the resistance has been cut out, after which the motor is ready for work. Reference to the diagram shows that as the resistance is cut out of the armature circuit it is introduced into the field-magnet circuit. The resistance of the field-magnet winding is, however, much greater than the resistance of the starter, so that the field current is only slightly affected by this introduction. As a matter of fact, in the machine used in standard Marconi sets, the connections are such that the resistance is again cut out of the field circuit when the handle finally comes to rest on the last stud. The actual connections will be given later when dealing with the particular apparatus employed.

No-volt Release.—If the magnetising current be suddenly cut off when the machine is rotating at a high rate of speed there will be no setting-up of a back E.M.F. The result would be a great rush of current through the armature and a consequent burning of the conductors. In order to provide against the risk caused by an accidental cutting off of this current, a small electro-magnet is inserted in the field circuit in such a position that it exerts a sufficiently strong attractive power over a small piece of iron carried by the starter regulating handle to hold the latter in position on the final stud, against the force exerted by an antagonistic spring also connected to the handle. This electro-magnet loses its holding power as soon as the current ceases to flow through its winding,

and the handle is released, and under the action of the antagonistic spring flies back to its original position, thus also cutting off the current through the armature coils and causing the motor to come to a standstill.

Of course, such an interruption of the current through the field circuit, and continuation of the current through the armature circuit, only takes place when a break occurs in the former circuit. This electro-magnetic release, or no-volt release as it is usually called, also prevents an accident of another kind. If the handle of the starter were fixed in its final position by means of a hook or catch of some description, it would remain in this position even if the supply of driving current were cut off from, say, the engine-room. Now, if the supply were to be suddenly switched on again from the engine-room, it is seen that it would be equivalent to starting the motor under conditions which it has been explained must be avoided. That is to say, it would be the same as trying to start up with too strong an armature current, and disastrous results would follow.

Over-load Release.—In large machines another electro-magnet is often inserted in the main circuit in such a position that if the current becomes too strong for the safety of the machine, the no-volt release is short-circuited and the driving current thus switched off. This will be more fully described later.

Dynamos and motors are specially constructed according to the current and voltage which they are required to produce or use. If, then, we have current at, say, 100 volts pressure and desire to use current at 300 volts, it is an easy matter to arrange for a motor driven by current at 100 volts to drive a dynamo constructed to deliver current at 300 volts. Of course a certain amount of power would be lost in the arrangement, as electrical energy is first converted into mechanical energy and the resulting mechanical power reconverted into electrical power. Such an arrangement of a dynamo and motor coupled together mechanically is called a motor-generator.

Rotary Converter.—Now, it has been stated that the currents induced in the armature of a dynamo are commuted into continuous currents by means of the commutator. Most ships' dynamos are constructed on this principle. For wireless telegraphic purposes we generally require the original

alternating current, and it is often convenient to obtain it by reconverting the commutated current back to its original state. For this purpose a machine called a rotary-converter is supplied.

In Fig. 52 it is seen that two complete rings have taken the place of the commutator shown in Fig. 44. If the two brushes connecting the external circuit be placed one on each of these rings the current in the external circuit is also of an alternating character. In a type of generating machine called an alternator such rings are provided instead of the commutator.

The rotary-converter is fitted with both these arrangements — namely, a commutator and a pair of slip-rings.

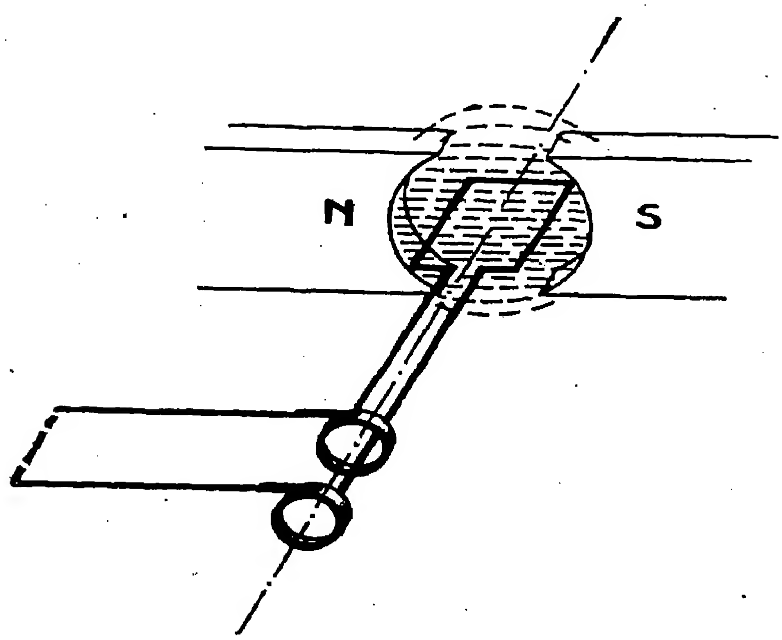


FIG. 52.—Use of Slip Rings.

Direct current from the ship's dynamo is brought to the commutator end of the armature and is used to drive the machine as a motor. Tappings are taken from the armature coils to the slip-rings, and when an external circuit is joined across these rings alternating current is forced through it. Figs. 53 (*a*) and 53 (*b*) illustrate the arrangement in a simple way. The same lettering is used in each figure. A and B are two carbon brushes making contact with the bars, C and D, of the commutator, E; F and G are two slip-rings, with which the carbon brushes, H and K, are making contact. From the points L and M on the armature coil CLMD, tappings are taken to the slip-rings. Now, when C is vertically above D, as shown in Fig. 53 (*a*), and if the current enters at the brush A, a portion will pass through the armature coil, CLMD, and be used to drive the armature round. If an external circuit be joined between H and K, it will be in shunt with the part LM of the coil CLMD, and consequently a certain

current, depending for its value on the resistance of the external circuit, will pass through it. The direction of the current through the various parts of the armature and external circuits is shown by means of the arrow-heads, and in Fig. 53 (*a*) it is seen that the direction in the external circuit is from K to H. After the coil has passed through half a revolution, however, the position of the commutator bars C and D with respect to the brushes A and B has been reversed. The slip rings have also turned through half a revolution,

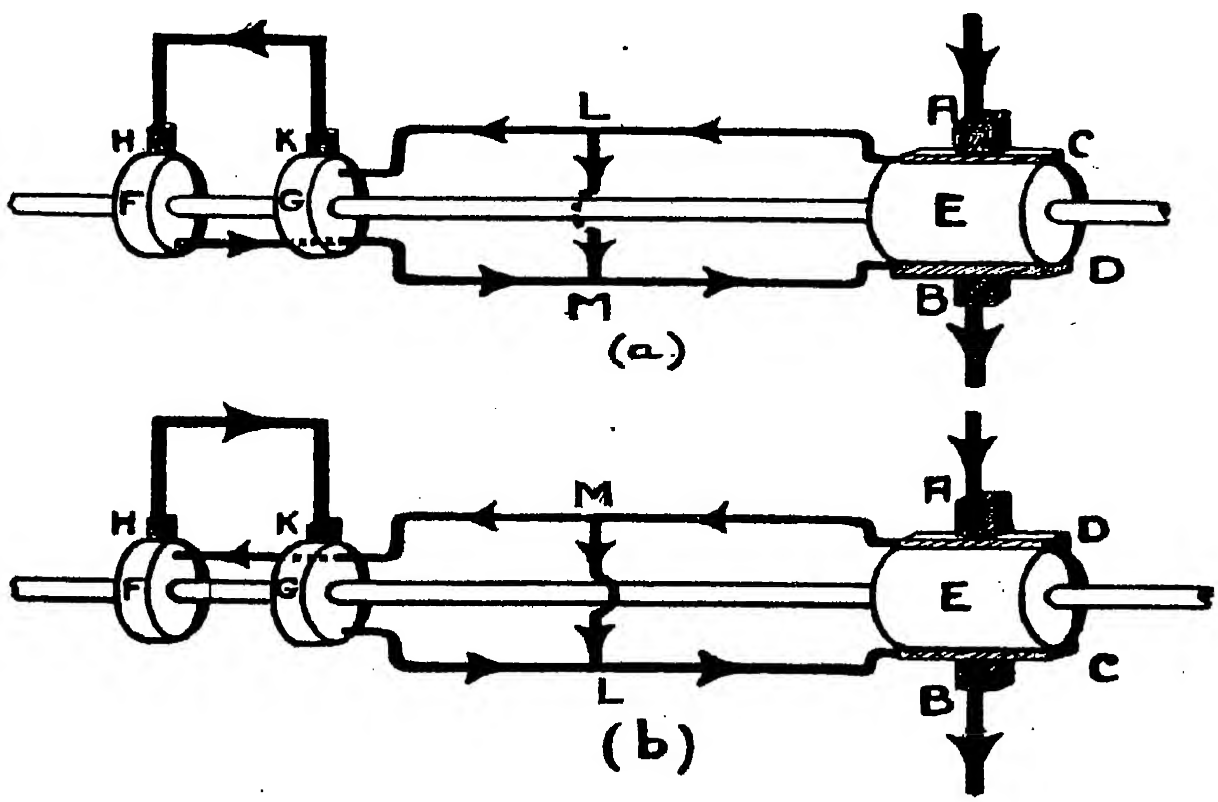


FIG. 53.—Conversion of D.C. to A.C.

the whole arrangement being mounted on the shaft XY; and by following the arrow-heads indicating the direction of the current it is seen that the direction through the external circuit is now from H to K. Thus in one complete revolution of the armature of such a machine, which is a two-polar machine, we have a complete cycle of alternating current.

The actual rotary-converter supplied with a Marconi standard ship's set ($1\frac{1}{2}$ kw.) is supplied with four field poles, and the arrangement of the armature windings and tappings is such that two complete cycles of alternating current are produced per revolution. Thus, if the machine is driven

at a speed of 1800 revolutions per minute the number of cycles per second is

$$\frac{1800 \times 2}{60} = 60$$

A brass plate is usually affixed to the framework of the machine with the following data (amongst other data)—50—60 ∿, indicating that the machine delivers alternating current at 50 to 60 cycles per second, according to the speed at which it is being driven.

Transformers.—A piece of apparatus similar in construction to the induction coil already briefly touched upon may be

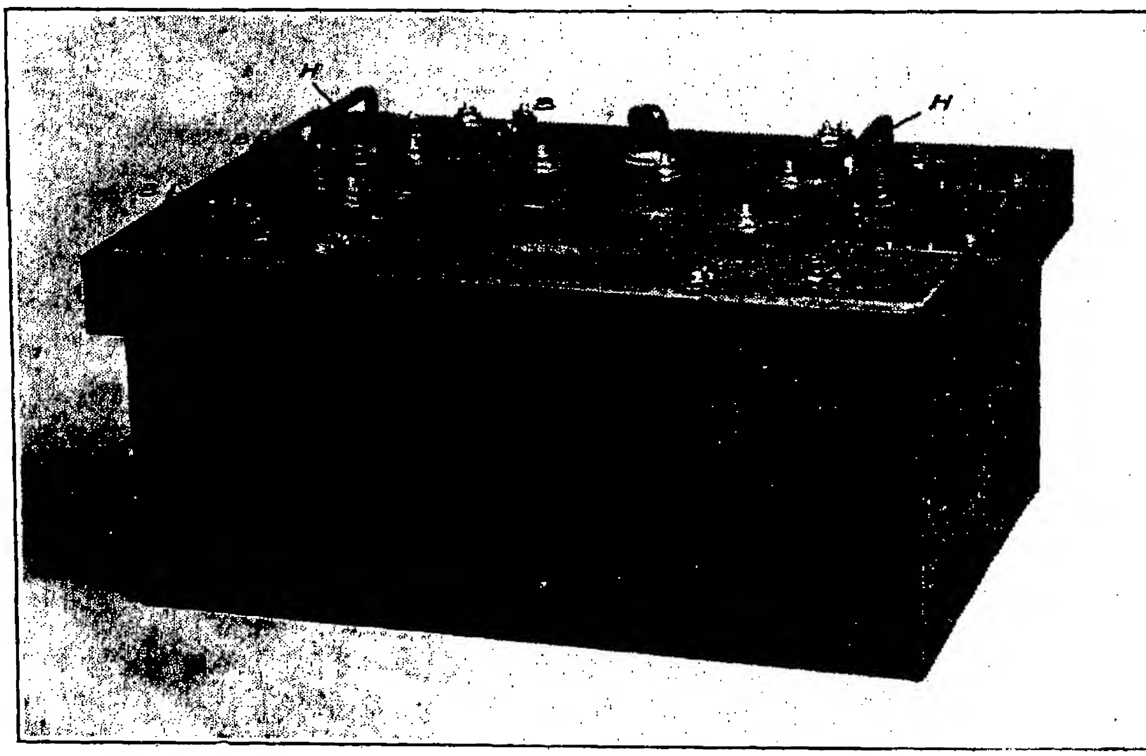


FIG. 54.—1½-K.W. TRANSFORMER.

B, Bolts for fixing Lid to Container.—C, Bolts for holding Coils in Position.—H, Iron Lifting Handles.—O, Wooden Plug for Oil Inlet.—P, Primary Winding Terminals.—S, Secondary Winding Terminals.

used in connection with alternating current. Two coils of wire may be so arranged that an induced current may be set up in the secondary at either a higher or a lower voltage than that of the primary current. No primary-circuit breaking device is necessary, as in the case of the direct-current induction

coil, because, as has been pointed out, the value of an alternating current is continuously changing, and therefore if such a current be used in the primary winding a continuously varying intensity of the magnetic field is taking place. It will be seen that there are four variations in the number of lines passing through the coils during one cycle of current. A gradual increase in one direction, a decrease in the same direction, an increase in the opposite direction, and a decrease in the same direction as the last increase.

If there are more turns in the secondary winding than in the primary, the secondary voltage will be higher, and the transformer is called a step-up transformer. If the primary has more turns than the secondary, the latter voltage will

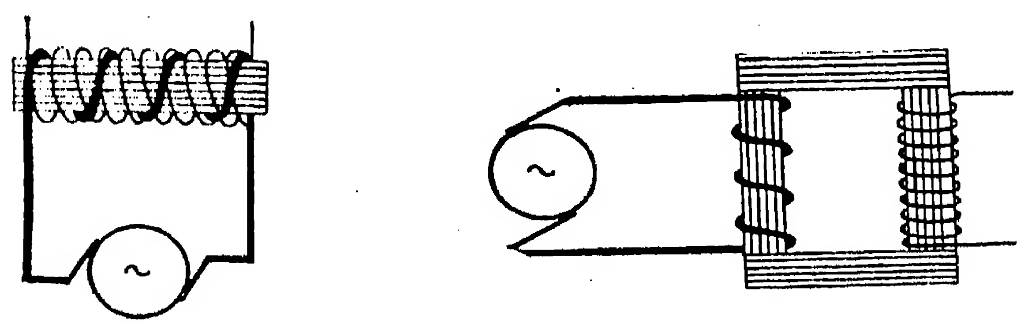


FIG. 55.—(*a*) Open-core Transformer. (*b*) Closed-core Transformer.

be lower, and the transformer is called a step-down transformer. A part of the primary may be tapped off to form the secondary, in which case the arrangement is called an auto-transformer. As in the case of the induction coil, an iron core is used to concentrate the magnetic field. In some cases the arrangement of the two coils is identical with that of the induction coil, when the transformer is said to be of the open core type (Fig. 55 (*a*)). Another type of transformer is, however, often used in which the core forms a continuous circuit, the primary being wound round one part of it and the secondary round another part, as in Fig. 54 (*b*). This is known as a closed-core transformer. The open-core type is used in the lower power sets of wireless apparatus and the closed-core type at high-power stations. The secondary current induced is of an alternating nature.

CHAPTER VIII.

INDUCTANCE.

Inertia—Self-induction—Inductance — Mass — Velocity — Acceleration—Experimental proof of inductance—Lenz's law—Measurement of inductance—Henry—Micro-henry—Analogy between mechanical and electrical inertia.

Inertia.—It is now necessary to consider a very important property possessed by all circuits in which an electric current is flowing. This is the property of self-induction, or, as it is more briefly called, "inductance."

The method adopted in most text-books to explain this property is to show the analogy that exists between it and mechanical inertia. A brief explanation of what is meant by mechanical inertia is therefore necessary.

When a man jumps on to a 'bus travelling at a high rate of speed he is conscious of having to grip tightly to the rail and feels a strong strain on the arms. After a little while he can relax the grip and maintain a footing on the vehicle without any difficulty. It is seen, therefore, that his body offers some resistance to an increase in the rate of motion from a walking or running pace to the pace of the 'bus. Again, if a man drops off the 'bus when it is travelling at a high speed he must run a little way or otherwise be thrown to the ground. From this we see that his body offers some resistance to a change from the high speed of the 'bus to the lower speed of walking.

Again, we know that a strong force is required to bring a heavy vehicle from a position of rest to a state of motion, but after the vehicle has once begun to move it only requires a small force to maintain this motion. If the force be suddenly removed, the vehicle does not immediately come to rest, but, unless brakes be applied, continues to move for some time. If some obstacle is placed in its way, disastrous results may ensue.

Now, the property in virtue of which a body resists any change of motion is called its inertia. A law showing the relationship between the motion, mass of a body, and the force required to overcome this inertia is very easily found.

If a mass of one pound be allowed to fall from a height, the force of gravity is the only force applied to it causing its motion. It is found experimentally that such a mass falls 16·1 ft. during the first second after it has been released. During the second second it is found to fall 48·3 ft., and during the third second it falls 80·5 ft. Its speed is thus increased or accelerated at the rate of 32·2 ft. per second per second. The force exerted on the mass by gravity is equal to the mass, and in the present case is a force of one pound. If, then, a force of one pound will accelerate a mass of one pound at the rate of 32·2 ft. per second per second, a force of one pound would only accelerate a mass of 32·2 pounds at the rate of 1 ft. per second per second. A mass of 32·2 pounds is called an engineer's unit of mass, therefore we can say that a force of one pound is required to give an engineer's unit of mass an acceleration of 1 ft. per second per second. If, then, we say a body has m units of mass, we easily see that the force required to give it an acceleration of a feet per second per second is obtained from the equation—

$$F = ma$$

Inductance.—It is stated that the inductance of an electrical circuit is comparable with mechanical inertia. The analogy existing between the two is so close that a very similar equation for an electrical circuit can be stated to the one given above.

Before considering the equation, however, it is better to compare an electrical circuit with the 'bus spoken of at the beginning of this chapter.

It has been stated that unit current signifies the passage of unit quantity past any point in a conductor in unit time.

That is to say, that current, instead of being expressed as ampères, may be expressed as coulombs per second; or as the total electrical mass moved per second. This may be compared with the mechanical mass of the 'bus, if due allowance is made for the fact that the mass of the 'bus is constant whatever its speed, whereas the electrical mass in the current increases with the electrical speed.

We have shown that the speed of a 'bus is only gradually acquired on the application of a certain force. We might expect, then, that the strength of current in a circuit gradually rises on the application of electrical pressure. We have stated that on the force being withdrawn from the moving 'bus it comes gradually to rest after having travelled some distance. We might expect, then, that a current would continue to flow for some time after the electrical pressure has been withdrawn. Finally, we have stated that if a moving 'bus is suddenly stopped by the interposing of some obstacle a smash takes place. We might then expect that if an attempt were made to suddenly stop the passage of a current some analogous display of energy would take place.

In a great number of cases it is very difficult to find any such results. If an electrical circuit supplied with a measuring instrument be suddenly switched on to a source of supply, the needle of a good instrument immediately comes to a fixed position, indicating a steady current. According to Ohm's law this is exactly what should happen, for it states that $C = \frac{E}{R}$. If the current be suddenly switched off, the needle does not usually indicate a gradual falling of current, neither does this sudden stoppage of the current bring about anything resembling a mechanical smash-up in a great number of cases.

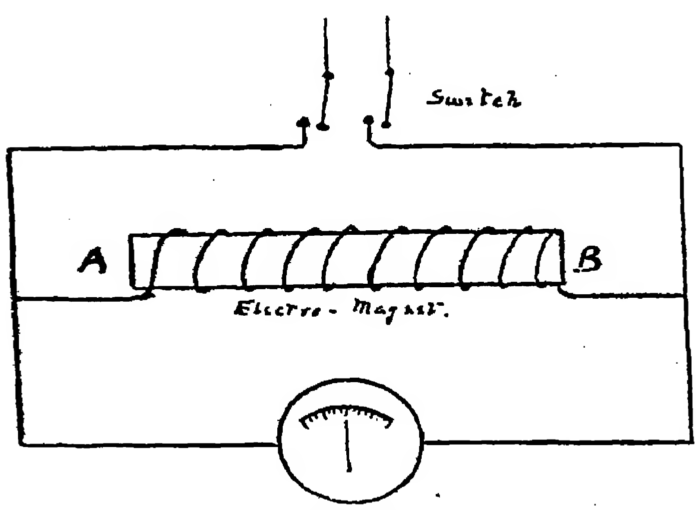


FIG. 56.—Experiment on "Inductance."

In a circuit containing a large electro-magnet, however, the analogy holds good. The current is found to mount up gradually on making the circuit, and on breaking it suddenly the current still continues to flow. Ordinarily, if a circuit be suddenly broken, there is no path along which it may continue to flow, so that arrangements must be made to provide another path simultaneously with the cutting off of the supply circuit.

Fig. 56 shows a simple arrangement for demonstrating that the current continues to flow even after the supply has been cut off.

Supply mains are connected through a switch to the ends of the winding of an electro-magnet, AB. A galvanometer is joined across the points A, B. When the switch is closed a current passes through the electro-magnet and part of it through the galvanometer, producing a deflection in the latter towards, say, the right. The current passes through the electro-magnet in a direction from A to B. If the switch be suddenly opened, the galvanometer needle is found to be deflected to the left, showing that the current is still flowing through the electro-magnet in the same direction—namely, from A to B—and through the galvanometer from B to A.

Again, the third and final effect is produced in the form of a spark. If the current through a very powerful electro-magnet be interrupted suddenly, a large spark may take place at the point of interruption, and the current continuing through the coil may be at a pressure sufficiently powerful to break down the insulation of the windings unless special precautions are taken. It is usual in the case of large magnet windings to put a resistance across the ends at the same time that the circuit is broken, thus allowing a suitable path through which the current may expend itself.

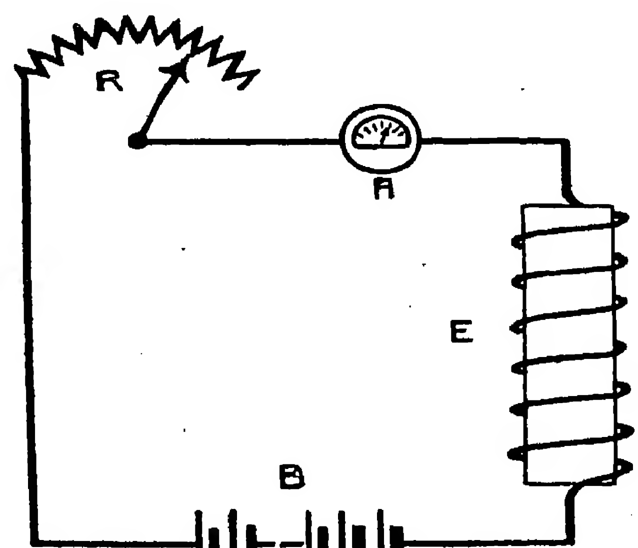


FIG. 57.—Experiment on "Inductance."

In order to investigate the conditions governing this action let us consider the accompanying figure (Fig. 57). B is a battery connected through a variable resistance, R, and a current-measuring instrument, A, to an electro-magnet, E.

Before any current is passing through the magnet windings no lines of force exist with the exception of those due to the residual magnetism of the core. When the battery is switched on a current flows and increases the number of these lines. It has been stated in a previous chapter that whenever the number of lines of force linked with a conductor is varied, an E.M.F. is induced in that conductor. Therefore, if we

gradually vary the resistance R, thus by Ohm's law gradually varying the current through the circuit, we continuously vary the number of lines of force linked with the magnet and produce in the magnet coils an induced current.

Lenz's Law.—Now Lenz experimentally proved that an induced current, by virtue of its electro-magnetic effect, always tends to stop the motion which produces it. The same result follows when the inducing current is started or stopped and the circuit remains stationary, for the effect on a neighbouring circuit of starting a current is the same as when the current is brought up from an infinite distance.

Therefore we see that the E.M.F. of the induced current is in a direction tending to stop any increase of the original current. If the current be slowly decreased, the number of lines of force is being altered in an opposite sense and the induced E.M.F. is consequently reversed. That is to say, the direction of the induced E.M.F. is such as to prevent the original current being decreased. Now, the rate at which the number of lines of force is being changed depends upon the rate at which the current is changing.

If we so arrange our circuit that a current of one ampère flows during the first second, a current of two ampères during the second second, a current of three ampères during the third second, and so on, we can say that we have an electric acceleration of one ampère per second. This can be further expressed as an electrical acceleration of one coulomb per second per second, and it is seen to be very similar to our expression for the acceleration of mass—*i.e.*, one foot per second per second.

Now, the unit of E.M.F., the volt, is by definition the E.M.F. induced in a circuit when the number of lines of force linked with it changes at the rate of one hundred million, or 10^8, per second.

If we suppose a circuit in which a current of one ampère produces 10^8 lines of force linked with it, we can say that a current accelerating in it at the rate of one coulomb per second per second is causing an increase of lines of force at the rate of 10^8 lines per second.

This increase is plainly setting up an opposing E.M.F. of one volt, therefore we may say that a pressure of one volt must be applied to the original current to overcome this back pressure in order to allow the current to accelerate at the rate stated. Such a circuit, in which a change of

current of one ampère per second, causes a hundred million additional or fewer magnetic lines to be linked with it, is said to have a unit coefficient of self-induction, or unit inductance. The unit of inductance is called the Henry.

Now if the current in a circuit is accelerating at more than one ampère per second, the back or opposing E.M.F. will be correspondingly greater. We can express this by saying that the force required to overcome the back E.M.F. is proportional to the rate of acceleration. Again, if the circuit is of such a type that the rate of increasing of the lines of force is greater than 10^8 for an acceleration of one ampère per second, the induced back E.M.F. will be still further increased and a corresponding increase will be required in the applied E.M.F. to overcome it. We can express this by saying that the force required to overcome the back E.M.F. is proportional to the rate of increase of lines of force per unit acceleration. But this rate of increase of lines of force divided by 10^8 gives us the inductance of the circuit; therefore we can say that the force necessary to overcome the back E.M.F. set up in a circuit by a constantly varying current through it is proportional to the electrical acceleration and to the inductance, or, if a represents acceleration in coulombs per second per second and L represents the inductance of the circuit, then the force required is $F = La$.

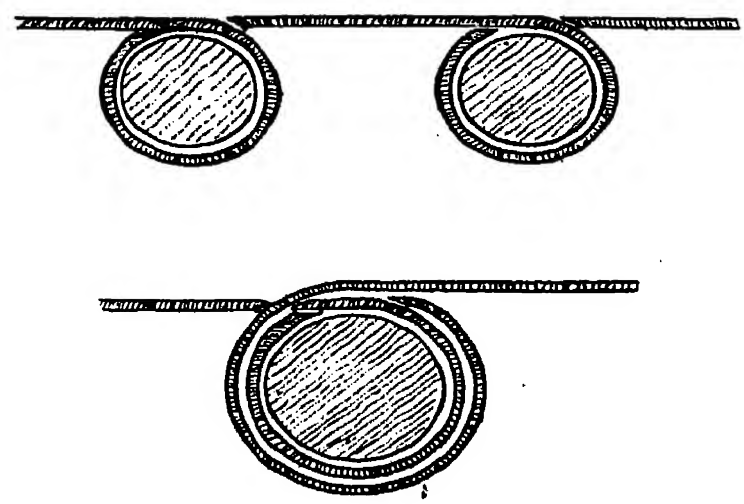


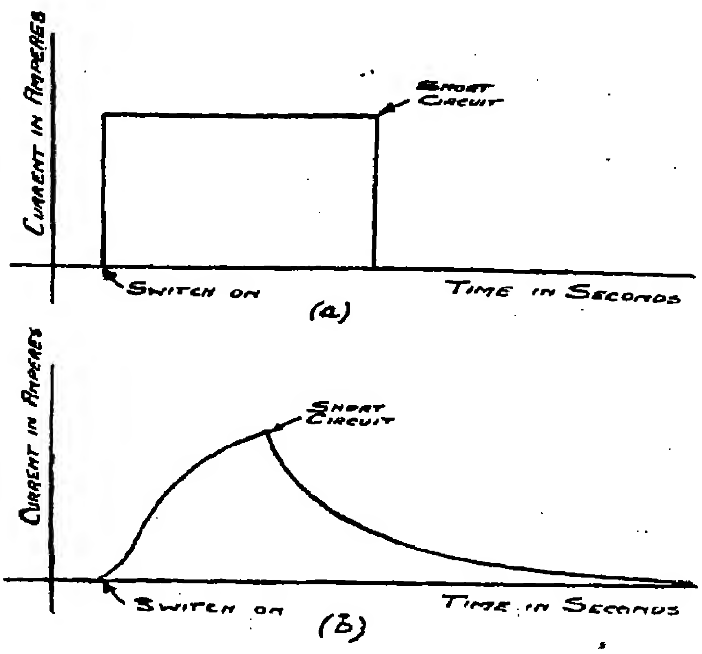
FIG. 58.—Linkages of Lines of Force with a Circuit.

This we see is very similar to the equation for the force required to overcome mechanical inertia due to mass and mechanical acceleration.

The inductance of a circuit depends on its shape and on the presence of iron in it, as these factors have a determining influence on the number of lines linked with a circuit.

In Fig. 58 a length of wire is given one turn round each of two pieces of iron. If a current be passed through the

wire, it is seen that the number of linkages is twice as great as it would have been had the wire only been taken round one piece of iron. If the wire is taken twice round one piece of iron each turn is linked with twice the number of lines and therefore we have four times the linkages, so we see that if n turns of wire are taken round a piece of iron in which N lines are set up by one turn a total linkage of n^2N lines is formed. This is the reason that the effects of inductance in a circuit containing a large electro-magnet are so strongly marked.



FIGS. 59 (*a*) and 59 (*b*).—Current Curves in Non-Inductive and Inductive Circuits.

Curves showing the difference between the currents in two circuits, one containing an electro-magnet and the other without, are given in Figs. 59 (*a*) and 59 (*b*). Where a continuous current is concerned the effects are only produced at the starting and stopping stages. When dealing with alternating currents, however, the current is continuously accelerating either in a positive or negative sense, and consequently the effects are considerable. More will be said on the subject of inductance later.

CHAPTER IX.

DIRECT AND ALTERNATING CURRENT MEASUREMENTS.

Current measurements—Direct current—Voltmeter—Ammeter—Arrangement of instruments in a circuit—Alternating current—Root mean square value—Application of Ohm's law to alternating currents—Impedance—Reactance.

MECHANICAL power is reckoned in foot-pounds per second. So electrical power may be reckoned in volt-coulombs per second. But since one coulomb per second is one ampère, electrical power is measured by the product of ampères and volts. Thus, there is unit power in a circuit when one ampère is flowing at a pressure of one volt. The unit of power is called the watt. For practical purposes a larger unit is used equal to 1,000 watts and called a kilowatt. The kilowatt is approximately equal to $1\frac{1}{3}$ horse-power, one horse-power being 550 foot-pounds per second.

In order to find the power of a circuit it is necessary to know the ampèrage and voltage, and instruments known as ampère meters (or ammeters) and voltmeters are used to indicate these values.

The Voltmeter.—Mention has already been made of the galvanometer as a means of detecting the presence of a current. If a dial be placed underneath the deflecting needle, it may be calibrated to show by a direct reading the value of the E.M.F. in any circuit. If resistances be placed in parallel in any circuit, the current through each part is inversely proportional to its resistance. That is to say, the greater the resistance the smaller the current. If two conductors be placed in parallel in a circuit, one being of low resistance such as the main conducting wire of a circuit, and the other being of high resistance such as a galvanometer coil or multiplier, the portion of the current passing through the

latter is very small. By Ohm's law the current is directly proportional to the E.M.F., so that the potential difference between the two points at which the parallel circuits are connected determines the amount of current passing. If the P.D. be doubled the current is doubled. But it has been pointed out that any increase of strength of the current passing through a multiplier increases the deflection of the needle; consequently an increase of potential difference will cause an increased deflection. A galvanometer suitably calibrated may therefore be joined in shunt across any two points of a circuit to indicate the difference of potential between them, and such an instrument is then called a *voltmeter*. Many different forms of voltmeter are manufactured, and a great many devices are introduced for such purposes as increasing the sensitiveness or for bringing the indicating needle to rest quickly.

Usually the resistance of the meter is not sufficient, so that additional resistance is added in series.

For details of the various types the operator is referred to any of the numerous text-books which have been written on the subject. The chief point to remember about the voltmeter is that *it is always joined in shunt* and only takes an extremely small portion of the current to operate it.

A small key or switch is often used in connection with a voltmeter in order that it may be put in circuit when required. The connections of the instrument to the circuit are shown in Fig. 103. A_1 and B_1 represent two points on a circuit between which it is desired to measure the P.D. B_1 is connected directly to one end of the voltmeter coil, while A_1 is connected to the other end only when the key, K, is depressed.

The Ammeter.—Because this instrument is designed to measure the total current flowing in a circuit, it must be of dimensions large enough to take the whole current and must be inserted in the main circuit. It also depends upon the same principle as the galvanometer, but in this case the coil of wire must be of low resistance. It is therefore constructed of thick wire of a few turns. Ammeters designed to measure heavy currents usually have a straight bar or strip of low temperature coefficient metal in parallel with the coil, so that only a fixed percentage of the current passes through the latter. When the instrument has been once calibrated

the same bar or shunt must, of course, always be used across the coil. It is usually found advantageous to provide some means of short circuiting an ammeter, as this is the best way to cut it out of circuit. Fig. 103 shows the means adopted. A and B are two brass blocks connected respectively to the ends of the ammeter coil and to the main leads. When the instrument is not in use a brass plug is inserted between the blocks, a path of much less resistance being thus afforded for the main current.

It has been stated that the value of the current and E.M.F. in an alternating current is continuously changing. The instruments for measuring the values of direct current are therefore unsuitable for use with alternating current.

Root Mean Square.—The heat produced in a conductor is proportional to the square of the current and to the effective resistance of the conductor. A means of finding out the value of an alternating current is thus afforded. A direct current may be passed through a known resistance and the amount of heat generated may be measured. If an alternating current be passed through a conductor of the same effective resistance and the heat be measured, a comparison of the two results will give a comparison of the effective values of the squares of the two currents, and the square roots of these values will give the ratio between the values of the currents. The effective value of ampères and volts of an alternating current, following the sine law, is found to be 70·7 per cent. of the maximum values; thus if a sinusoidal alternating current reaches a maximum pressure of 100 volts, the effective, or virtual, value, as it is called, is 70·7 volts. The virtual value of the current and E.M.F. is called the root-mean-square-value, because it is the square root of the mean of the squares of all the instantaneous values of the alternating current.

Measuring instruments are designed to give direct readings of the virtual values of alternating current, but it is not proposed to give constructional details, as such information may be obtained from other text-books. The ammeter and voltmeter supplied with a standard Marconi set are of this type, and the conventional sign used to represent alternating current (*i.e.* $\sim$) is invariably marked on the dial of such instruments.

Application of Ohm's Law to Alternating Currents.

In a direct current circuit we have seen that $C = \dfrac{\text{E.M.F.}}{R.}$

In an alternating current circuit account has to be taken of the inductance, because the E.M.F. has to overcome the back E.M.F. of inductance in addition to the resistance.

In an alternating current circuit of inductance L, in which a current of I virtual ampères is flowing at a frequency of n cycles per second, the back E.M.F. is equal to $2\pi nLI$ virtual volts. The back E.M.F. is at its greatest value when the current is increasing at the greatest rate, namely, at the moment it is rising from zero value, and is at its smallest value when the rate of change of the current is lowest, namely, when it is at its maximum value. It is thus seen that the back E.M.F. follows a curve exactly one quarter period behind the current curve.

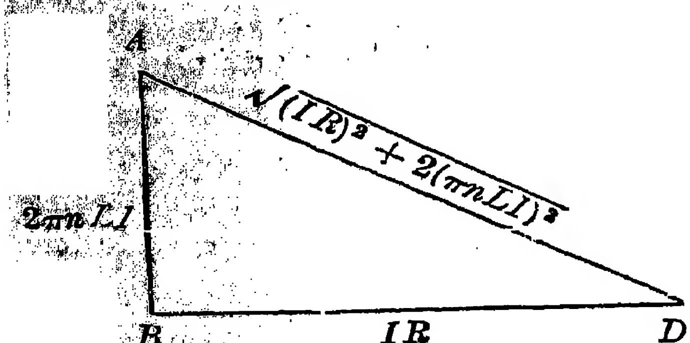


FIG. 60.—Determination of Impressed E.M.F.

The triangle ABD, Fig. 60, may represent the following dimensions :—

BD represents the electromotive force required to overcome the resistance, which by Ohm's law is equal to the product of the current and the resistance. This can be written IR.

BA represents the force required to overcome the back E.M.F. due to inductance which has already been given as

the total impressed E.M.F.
ance and inductance.
course, equal to the square
le lines AB and BD. There-
equals $\sqrt{I^2R^2 + (2\pi nLI)^2}$,
current circuit becomes

$$\frac{\text{Virtual volts}}{\sqrt{(R)^2 + (2\pi nL)^2}}$$

alled the impedance of the cir-
lone being called the reactance.

CHAPTER X.

CONDENSERS.

Condenser—Capacity—Dielectric—Specific inductive capacity or dielectric constant—Leyden jar—Farad—Micro-farad—Calculation of capacity—Series or cascade arrangement—Parallel arrangement—Proof of formula used for calculation of capacities in series—Condenser compared with spring—Compared with hydraulic circuit.

IN the first chapter it was shown that certain bodies could be charged with electricity, and some were stated to be positively charged while others were said to be negatively charged.

This property possessed by certain bodies of holding a charge of electricity is made use of in the construction of a piece of electrical apparatus called a condenser.

The main discovery was made by German scientists long ago. At a time when electricity was looked upon as a fluid a certain scientist, whilst attempting to collect some of this fluid in a bottle, received a very nasty shock. He half filled a glass jar with water, into which he placed a metal chain to be used as a conductor between an electricity-producing machine and the water. When he considered the water sufficiently highly charged he attempted to remove the chain with one hand whilst holding the jar with the other. The jar then discharged a current through his body, producing the shock mentioned.

After this many experiments were made, but a conception of the working of a condenser may be easily obtained without entering into the details of these.

Whenever a positive charge is given to any body a negative charge of equal value is created at some other point.

When two bodies are charged with electricity of the same sign a force of repulsion is manifested between them, just as a force of repulsion exists between two like magnetic poles.

Again, two bodies charged with electricity of opposite signs are found to exercise a force of attraction between each other. This force of attraction and repulsion is exerted through substances which are generally known as non-conductors. Thus, if a sheet of glass be placed between two oppositely charged bodies these bodies are still found to attract each other. In Fig. 61, A and B are two brass discs, and C is a sheet of glass placed between them. If a positive charge be given to B, positive electricity will be repelled to earth from A, if the latter be connected by means of a conductor to earth, leaving a charge of negative electricity on it. This negative charge attracts the positive electricity on B to the face of the disc nearer the glass, and a further positive charge may be applied to it. We thus see that an arrangement of this kind is capable of holding a greater charge than either of the two discs taken separately, and hence such an arrangement may be called an electrical condenser.

If a charged body be brought near an uncharged body the latter is found to be oppositely electrified at the part nearer the charged body, and similarly electrified at the part most remote from it.

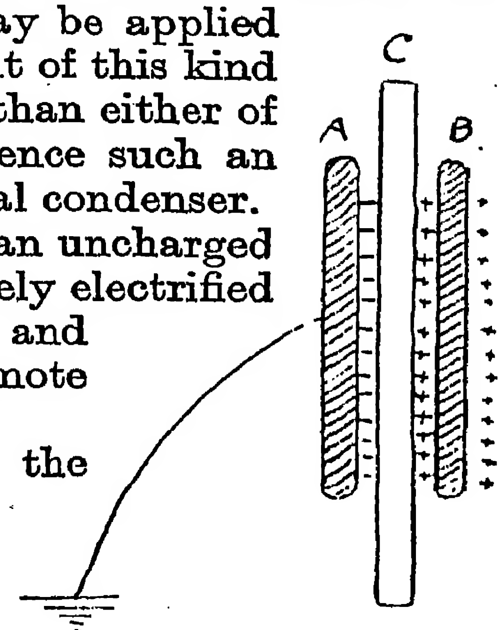


FIG. 61.—Action of Condenser.

If the electrified body be removed, the second body loses this electrification. Such electrification is said to be due to electro-static induction. Lines of force radiate from a charged body just as they have been shown to radiate from the poles of a magnet.

Specific Inductive Capacity.—Some substances seem to offer an easier path for these electro-static lines of force than others. It is found that when a sheet of glass is placed between two conductors the arrangement is capable of holding a greater charge than when air alone separates them. In order to compare the relative capabilities of different materials in this respect, the "specific inductive capacity" (as this quality is called) of any material is compared with that of air, which is always taken as unity. Thus, if glass is stated to have a specific inductive capacity (or dielectric constant, as it is sometimes called) of six, we understand that the capacity of a condenser in which glass is used to separate the two plates is six times that of a condenser of equal size, but using air as

the separator. The capacity of a condenser is the amount of electricity necessary to raise the difference of potential of its two terminals from zero to unity,—that is, to raise its potential through one volt.

Capacity.—A condenser is said to be of unit capacity when a charge of one coulomb causes a difference of potential of one volt between its terminals. The unit of capacity is called the "farad," but as this is much too large for practical purposes a smaller unit, called a "micro-farad," is used. This is one-millionth part of a farad.

The capacity of a plate condenser may be proved theoretically and experimentally to be equal to the area of the plate multiplied by the dielectric constant, and divided by 4π times the distance between the plates when the condenser is of such a type that the distance between the plates is very small compared with the area, or—

$$K = \frac{\text{Area in sq. cms.} \times s}{4\pi t}$$

where t equals the distance between the plates in centimetres and s equals the dielectric constant.

The capacity given by this formula is in electro-static units and must be divided by 900,000 to reduce it to micro-farads.

Leyden Jar.—The best known form of condenser is the Leyden Jar. This consists of a flint glass jar coated for about one-third of its height on its inner and outer surfaces with tinfoil. The mouth of the jar is fitted with a wooden stopper, through which a conducting rod, with chain or contact springs at its end, passes to make connection with the inner coating. The upper end of this rod is usually fitted with a brass ball or terminal. A number of such jars may be joined in either parallel or series in a similar manner to a battery of cells. When a number of jars are connected in parallel it is merely equivalent to increasing the area of the plate, and consequently a total capacity equal to the sum of the separate capacities is obtained. When a series arrangement is made (sometimes called a cascade arrangement) the operation is equivalent to increasing the distance between the plates, and a smaller total capacity results.

Calculation of Capacity.—The calculation of the total capacity of separate capacities in series is found from the

following rule. The reciprocal of the total capacity is equal to the sum of the reciprocals of the individual capacities, or

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \text{ etc.}$$

This equation may be proved as follows :—

Fig. 62 represents *n* jars connected in cascade or series.

The outer coating of the first jar is connected to the inner coating of the second, and so on throughout the series. All the jars except the last have their outer coatings as well as their

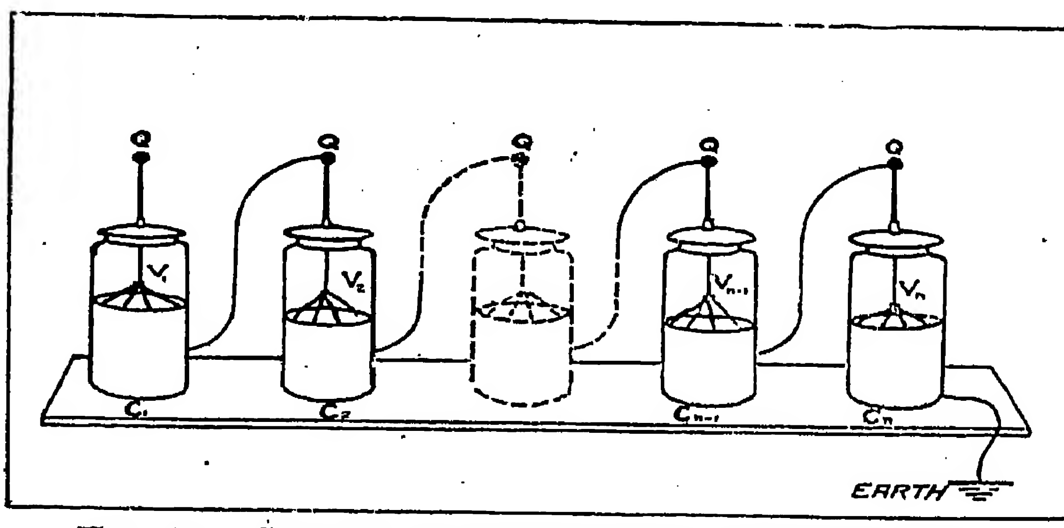


FIG. 62.—Capacity of Series Battery of Leyden Jars.

inner coatings insulated. The outer coating of the last jar is connected to earth.

Suppose a charge Q be given to the inner coating of the left-hand jar.

This charge Q attracts or induces a negative charge, which can be written $-Q$, on the outer coating of the first jar, and repels a charge Q to the inner coating of the second, and so on throughout the system. Thus the charges of all the jars are the same.

Let the potential of the inner coating of the first jar be V_1, and the potentials of the successive inner coatings of the other jars be V_2, V_3, V_4 . . . . V_n, and let the capacities of the respective jars be K_1, K_2, K_3 . . . . K_n.

If Q is the number of coulombs displaced through a condenser when the potential difference between the plates is one volt, we shall have V times that displacement when V volts

are applied on account of the proportionality of quantity to pressure. But we have seen earlier in this chapter that Q is numerically equal to K, the capacity.

Therefore the quantity in coulombs is equal to the product

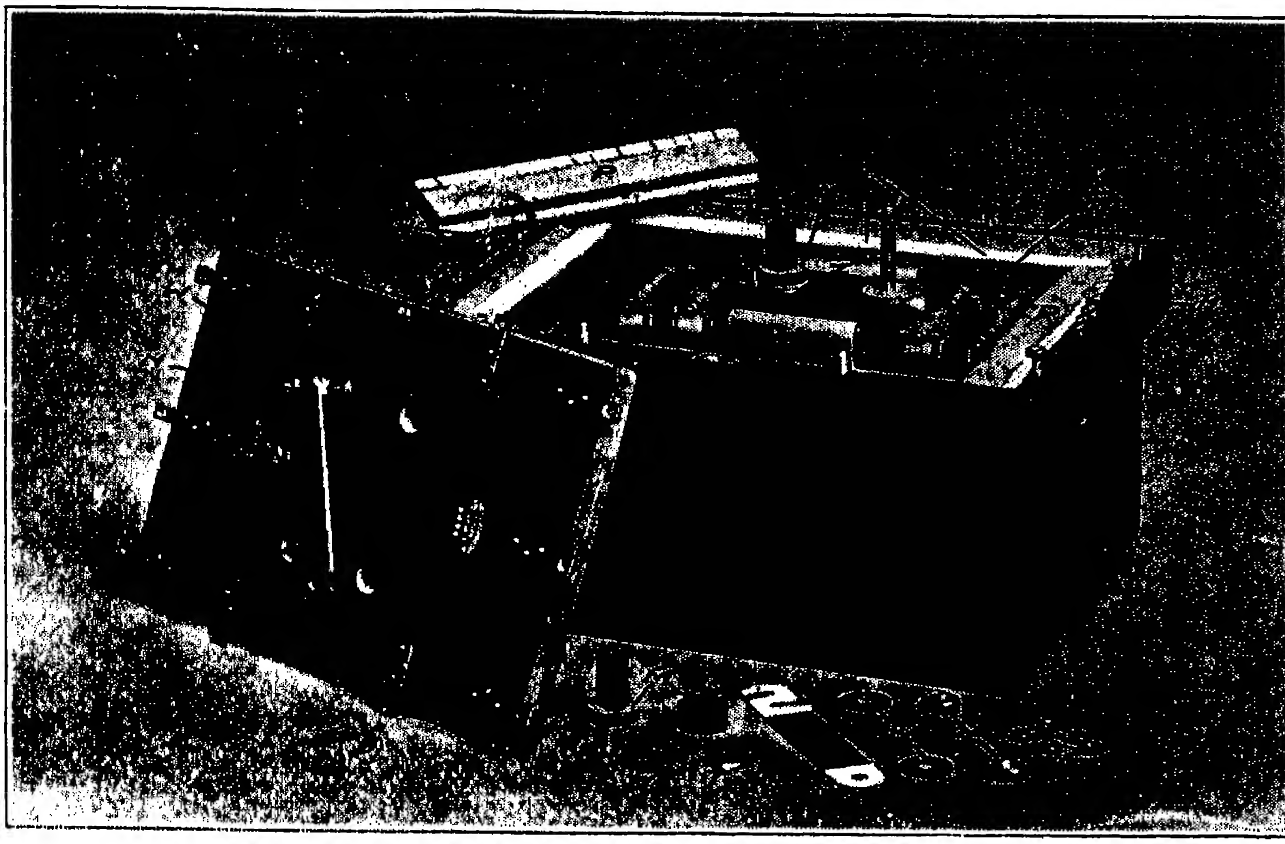


FIG. 63.—HALF-PLATE CONDENSER (OPEN).

B, Ebonite Bush.—C, Chamois Leather Pad.—F, Iron Nuts for holding Lid in Place.—H, Rope-lifting Handles.—L, Lead Lining.—M, Thin Leather Washers.—N, Hexagonal Brass Nuts.—O, Wooden Plug for Oil Inlet.—P, Cork Packing Pieces.—R, Ebonite Rings.—S, Brass Connecting Straps.—T, Thin Nuts.—W, Brass Washers.—Z, Zinc Cradle.

of the capacity and the voltage to which the condenser has been raised by a charge, or—

$$Q = KV.$$

From this equation we obtain a series of similar equations in connection with the cascade arrangement.

The potential of the first jar is equal to the difference of potential between its inner coating and the inner coating of the second jar, because the latter is connected to the outer coating of the first.

Therefore, because

$$Q = K_1(V_1 - V_2)$$

$$(V_1 - V_2) = \frac{Q}{K_1}$$

and in a similar way

$$(V_2 - V_3) = \frac{Q}{K_2}$$

$$(V_n - O) = \frac{Q}{K_n}$$

the latter potential being obtained because the potential of the outer jar is zero, as it is earth connected.

The sum of all the right-hand sides of these equations is equal to the sum of all the left-hand sides. Adding them all together, then we get

$$V_1 = \frac{Q}{K_1} + \frac{Q}{K_2} + \frac{Q}{K_3} + \frac{Q}{K_4} + \frac{Q}{K_5} \cdots\cdots \frac{Q}{K_n}$$

or

$$V_1 = Q\left\{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}\right\}$$

But if K be the total capacity of the system

$$V_1 = \frac{Q}{K}$$

Substituting the value of V_1 in the last equation we get

$$\frac{Q}{K} = Q\left\{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}\right\}$$

Dividing each side by Q we finally get

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} \cdots\cdots \frac{1}{K_n}$$

which it was desired to prove.

Action of Condenser.—A simple way to understand the action of the condenser is to compare it with a spring, and, as in the case of inductance and inertia, it can be shown that the equation showing the relationship between the force and displacement of a spring is very similar to the equation showing

the relationship between the force and electrical displacement of a condenser.

Fig. 64 shows a spring carrying a pan at its lower end and attached to a horizontal beam at its upper end. If a weight of one pound be placed in the pan the spring will stretch through a distance which we will call Y.

It is found that the distance through which the spring has stretched is exactly proportional to the force applied.

That is to say, if two pounds are placed in the pan the spring is found to stretch twice the distance that it does with a force of one pound. Y is called the yield constant of the spring.

It can be seen that if a force of F pounds be applied, the displacement, which may be represented by the letter s, would be equal to the product of the yield constant and the force applied, or $s = FY$, which may be expressed as :—

$$F = \frac{s}{Y}$$

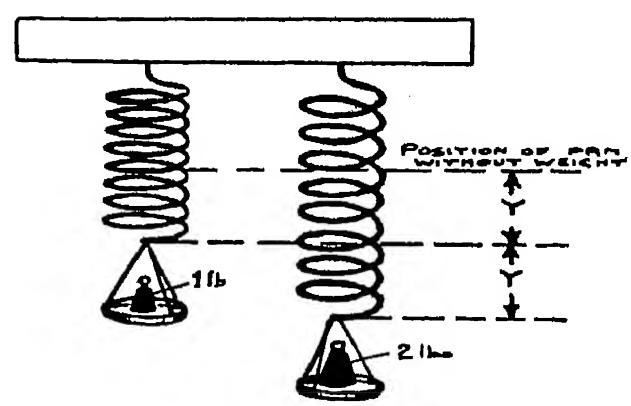


FIG. 64.—Condenser explained by Analogy with Spring.

Thus we see that any force applied to a spring is equal to the mechanical displacement divided by a certain constant, which is called the yield constant. In a condenser it has been shown that the electrical force, or voltage, applied is equal to the electrical displacement or quantity divided by a certain constant called the capacity.

The insulating material separating the two conductors of a condenser is called the dielectric. It has been shown that electric influence acts more strongly through glass than it does through air, but it does not follow from this that glass is the weaker insulator. In fact, it takes less voltage to break down the insulation of a given thickness of air, than the insulation of an equal thickness of glass. Glass therefore offers an easier path than air for the electrostatic lines of force, but at the same time, it is a better insulator.

Several considerations have to be taken into account in the design of a condenser.

Thus, if very high pressures are to be used, care must be

taken that the insulating properties of the dielectric are sufficiently good to withstand the pressure. If a large capacity is desired, the area of the opposing conductors must be considerable.

If large capacity is desired for use with high pressures, it can be seen that the condenser will take up considerable space.

In many cases, however, a large capacity is required for low pressures, and consequently, as the dielectric need only be thin, it is possible to build up a condenser satisfying the conditions which will only take up a small space. Therefore

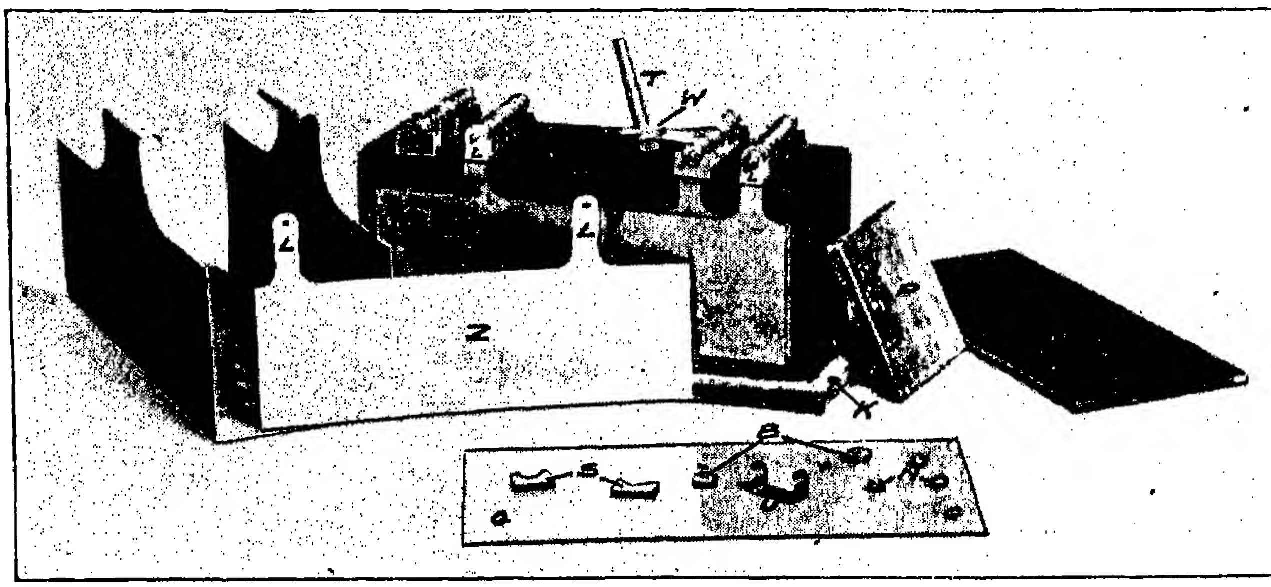


FIG. 65.—HALF-PLATE CONDENSER PARTS.

B, Brass Washer.—C, Zinc Cradle.—G, Glass Plate.—K, Cork Sheet.—L, Lugs of Zinc Plates.—N, Brass Nuts for Connecting Bolts.—P, Wooden Packing Pieces.—S, Leather Stool.—T, Brass Terminal.—U, U-shaped Copper Strip Connection.—W, Thin Leather Washer.—Z, Zinc Plate.

in a standard set of wireless apparatus, one finds condensers of different types suitable for different work, which will be dealt with in order as they appear in the different circuits.

A very good idea of the action of a condenser may be gathered from a consideration of Figs. 66 and 67. The first shows a water circuit, in which A is some form of pump, B is a chamber in the circuit, and CD is an elastic partition which is so fixed across the chamber as to prevent the passage of water from one side to the other.

If a force be applied by means of the pump, the elastic partition will stretch and there will be a displacement of water

through the circuit, which depends on the amount of "give" in the partition under the applied pressure. If the pressure be sufficiently increased, the partition will break down and the water will then circulate uninterruptedly. It is readily seen that the strength of the partition depends on its thickness, and the amount of displacement depends on its area.

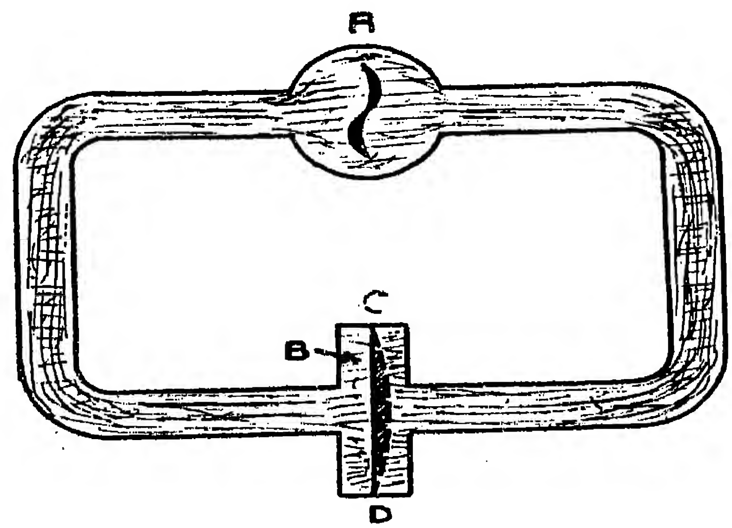


FIG. 66.—Condenser explained by Water Analogy.

In Fig. 67 an electrical circuit is shown in which a condenser, consisting of two metal plates separated from each other by means of a sheet of glass, is connected through a galvanometer, G, to a scource of current supply, which may be applied or cut off by means of a key, K. Before the circuit is closed the galvanometer needle shows no deflection. On closing the circuit, however, a kick of the needle indicates the passage of a quantity of electricity, which it has been stated depends on the pressure applied and on the capacity of the condenser, which latter in turn depends on its area, dielectric constant, and the distance between two plates.

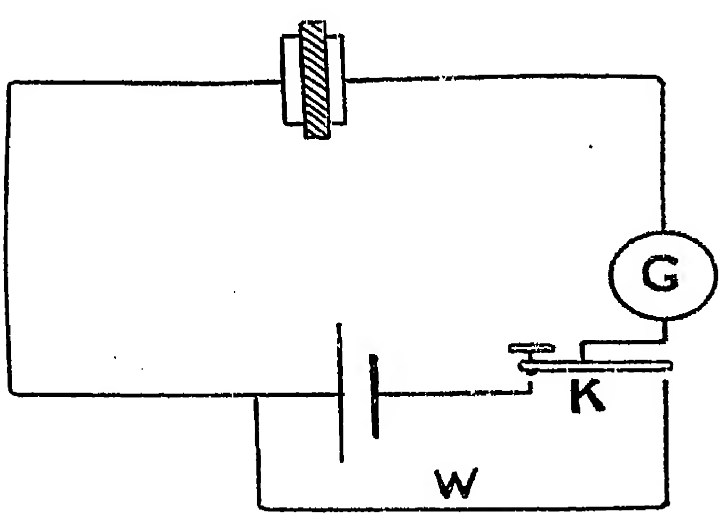


FIG. 67.—Condenser explained by Water Analogy.

If the pressure is increased beyond a certain point the dielectric will be pierced by a spark, and the condenser will break down. The dielectric thus corresponds to the elastic partition in the water circuit. Again, if the circuit be made and then broken, at the same time affording a circuit for a condenser discharge through the wire, W, shown in the diagram, the

galvanometer needle gives another kick, because a current due to the difference of potential between the two plates takes place through the circuit. In the case of the water circuit, if the force causing a stretching of the elastic partition be suddenly removed, the energy stored up in the elastic (similar to the energy in a spring) forces a flow of water in an opposite direction to the original displacement, and equal to it in quantity. Thus the analogy is complete.

PART II.

CHAPTER I.

ELECTRO-MAGNETIC WAVES.

Æther—Wave motion—Elasticity—Inertia—Electro-magnetic waves—Wave motion in water—Wave-length—Velocity—Frequency—Production of æther waves—High-frequency, or oscillatory, currents—Condenser discharge—Dimensions determining nature of condenser discharge—Resonance—Oscillation constant—Damping—Logarithmic decrement—Wave train—Number of oscillations per train—Spark gap—Plain aerial (P.A.)—Jigger coupling—Resonance curves—Mutual inductance—Coefficient of coupling—Percentage or degree of coupling.

THE student should now be in a position to apply the information contained in the preceding part of this treatise to the study of wireless telegraphy. Nowadays very few people are ignorant of the fact that wireless telegraphy depends on the production and detection of electro-magnetic waves.

"*Æther.*"—Certain scientific facts have led to the formulation of the theory that all matter is permeated by an imponderable medium, to which the name "æther" has been given. Æther cannot be isolated or detected by any of the senses. The phenomena of light were found to be explicable on the assumption that all matter is permeated by this medium, and because measurements showed that the velocity with which electro-magnetic effects are propagated through any dielectric is the same as the velocity of light, the theory was deduced that æther is the medium through which electro-magnetic energy is propagated in the form of waves.

Wave Motion.—In order that a wave motion may be set up in any medium, the medium must possess the property of elasticity and it must possess inertia of some sort.

When we speak of an elastic substance we mean a substance

which has the power of resisting any change of state produced in it, and in which a strain is produced by any force tending to produce such a change which on the removal of the force brings it back to its original state.

By inertia, as explained under the chapter on inductance, is meant the property of any matter in virtue of which it tends to resist any change of motion.

Thus, if the force producing a strain in an elastic body be removed, a certain motion takes place as the body is returning to its original state. This motion does not cease immediately the body has arrived at its exact original state, but by virtue of inertia continues a certain way, thus producing a state of compression where originally a state of rarefaction had existed. This over-reaching of the state of equilibrium continues for a certain time until the energy supplied by the original applied force is all frittered away.

Æther is a medium possessing such elasticity and inertia, and we must now consider what is meant by wave motion through such a medium.

It is convenient to compare electro-magnetic wave motion, which, of course, is not made evident to any of the senses, with some form of wave motion which can be seen. Probably every text-book on wireless telegraphy gives a description of wave motion through water as a means of explaining æther wave motion, and therefore because it seems to be such a popular method use is once more made of it here.

When any solid body is thrown into water, ripples are set up in the form of gradually increasing circles concentrically arranged round the point at which the body enters the water. The ripples nearest this point are very strongly marked, but as the distance from this point increases, they become less and less prominent, until finally, if the surface of the water be large enough, they die away altogether. To an observer it almost appears as though water were being transferred from the centre outwards in the form of a current, but if a piece of floating material be placed on the surface of the water within the influence of the waves, it is immediately seen that such is not the case. Instead of the floating body being carried outwards on what appears to be a current, it merely rises and falls, at one moment appearing on the top or crest of a ripple and the next moment appearing in the hollow or trough between this ripple and the next. It is thus seen that although there

has been no actual transference of matter from the centre of the disturbance to the outermost ripple, some form of energy has been propagated through the medium of the water.

The explanation is as follows :—When the body is thrown into the water it immediately causes a depression of the water under it. The water thus displaced exerts a pressure on the water immediately adjacent to it, with the result that this is also displaced. The only direction in which this adjacent water can be displaced is an upward one, because of the incompressibility of the great mass of water all round it. After the body causing the first displacement has disappeared below the surface, the originally displaced surface water returns to

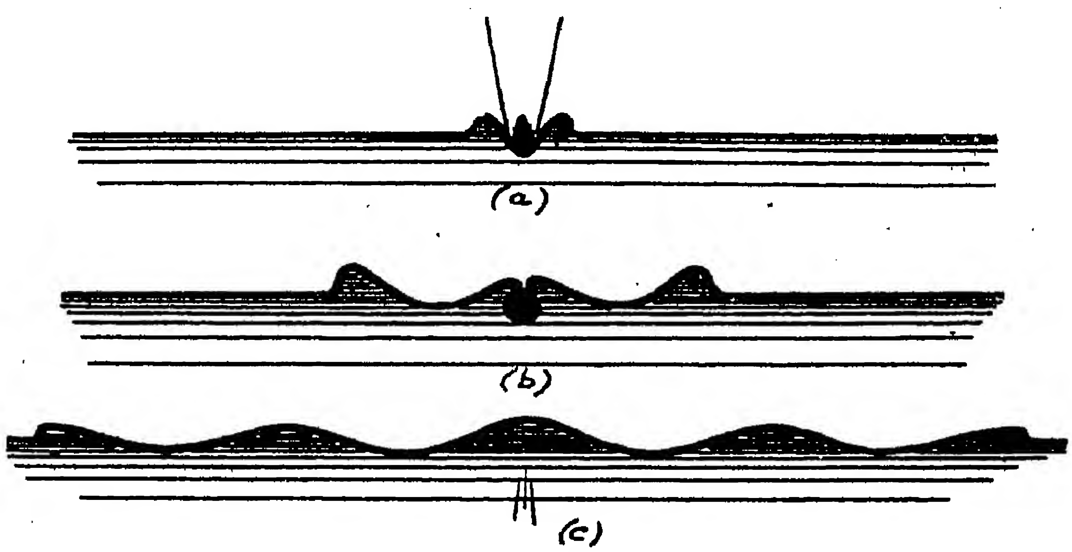


FIG. 68 (*a*), (*b*), and (*c*).—Production of Wave Motion in Water.

its former position. It does not, however, come to rest immediately on reaching this former position, but by virtue of its inertia oversteps the original level. At the same time, the adjacent water is going through the reverse of its first movement. Now, if we imagine the whole water affected as being a great number of very small particles, we can say that the wave motion consists of the motion in an upward and downward direction of each particle, the motion being transferred from each particle to the next in a horizontal direction. The different stages of the operation are shown roughly in Fig. 68 (*a*), (*b*), and (*c*).

Wave Velocity and Frequency.—Now the outermost visible ripple does not appear simultaneously with the dropping of the body in the water, and we see therefore that the wave

travels at a certain speed. The speed of wave motion through any medium depends on the square root of the ratio between the elasticity and the density of the medium.

Now the distance between the crest of one wave and that of the next is called the wave length, and it is clear that if, say, one hundred waves appear during the first second after the disturbing force is applied, the distance through which the first wave has travelled will be equal to one hundred times the length of one wave. Now this distance, having been travelled in one second, is the velocity of the wave. Hence if v represent the velocity, n represent the number of waves per second, and λ represent the length of each wave,—λ being the Greek "l" and pronounced lamda,—we may express the relationship between the three quantities as

$$v = n\lambda$$

Now the number of waves per second is called the frequency of the wave; consequently we say that the velocity equals the frequency multiplied by the wave length.

It has been experimentally proved that the velocity of electro-magnetic waves is the same as the velocity of light, which may be taken as 186,000 miles per second, or, roughly, three hundred million metres per second. Thus if the wave length or frequency of a wave be known it is easy to calculate the unknown value.

Production of Electro-Magnetic Waves.—In the chapter on the dynamo the sine curve was briefly dealt with. Such a curve represents what is known as a simple harmonic motion, and as an electro-magnetic wave has simple harmonic motion it can be represented by a sinusoidal curve.

It was explained that one complete reversal of direction of alternating current is called a cycle or period. The number of such cycles or periods per second, is called the frequency or periodicity of the particular alternating current dealt with. When the frequency is of the order of one or two hundred per second the current is called a low frequency current. When it is of the order of one thousand per second it is called a high frequency current. Currents can be produced, however, which alternate at a frequency of hundreds of thousands, or millions per second. Such a current of extremely high frequency is usually called an oscillating current. This last type of current is utilised for the production of electro-magnetic waves.

The construction of a machine capable of generating a large amount of power at such a high frequency is at present a matter of great difficulty, and consequently other means have had to be adopted. The method adopted in the Marconi and several other systems of wireless telegraphy depends upon the discharge of a condenser.

Condenser Discharge.—If a condenser be given a charge, and a wire of high resistance be joined across its terminals, a discharging current passes from the positively charged plate to the negatively charged plate, and the condenser is found to be in an uncharged state. The positive and negative electricity have neutralised each other. The discharge curve of the current passing through such a high resistance circuit is shown in Fig. 69.

If the experiment be repeated, using a wire of very little resistance in place of the wire of high resistance, the condenser is not discharged by the passage of a current in one direction only. A current flows from the positively charged plate to the negatively charged one, and does not cease at the point of neutralisation, but by virtue of inductance in the wire oversteps the mark, and gives a positive charge to the plate which was originally negatively charged, leaving a negative charge on the originally positively charged plate. When the force producing this overstepping of the point of equilibrium has been overcome, the difference of potential between the two plates is sufficient to force another current in the opposite direction, which current, like the first one, oversteps the point of electrical level. Each change of direction of the current is accompanied by a loss of energy due to the creation of heat, etc., so that in time the energy becomes so small that the backward and forward movement of current ceases altogether. The condenser is then said to have been discharged by means of an oscillating current, and the whole circuit is called an oscillatory circuit. A current thus produced may be represented as a curve as shown in Fig. 70.

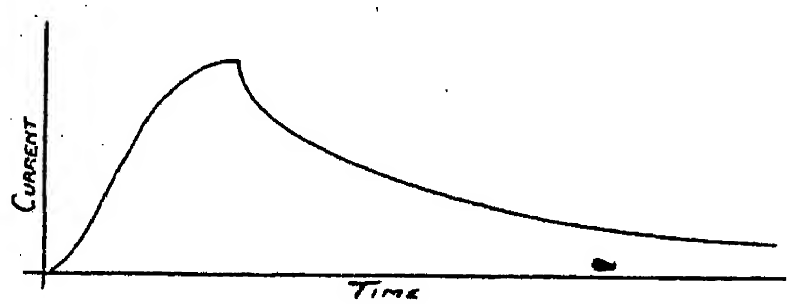


FIG. 69.—Condenser Charge, and Discharge through High Resistance.

The nature of a condenser discharge is determined by the relations which exist between the capacity, inductance, and resistance of the circuit. Let R represent the resistance, K the capacity, and L the inductance, then—

(1) If R is less than $\sqrt{\frac{4L}{K}}$ the circuit will be oscillatory.

(2) If R is greater than $\sqrt{\frac{4L}{K}}$ the circuit will be non-oscillatory.

(3) If R is equal to $\sqrt{\frac{4L}{K}}$ the circuit will be just non-oscillatory.

When a circuit carrying alternating current possesses

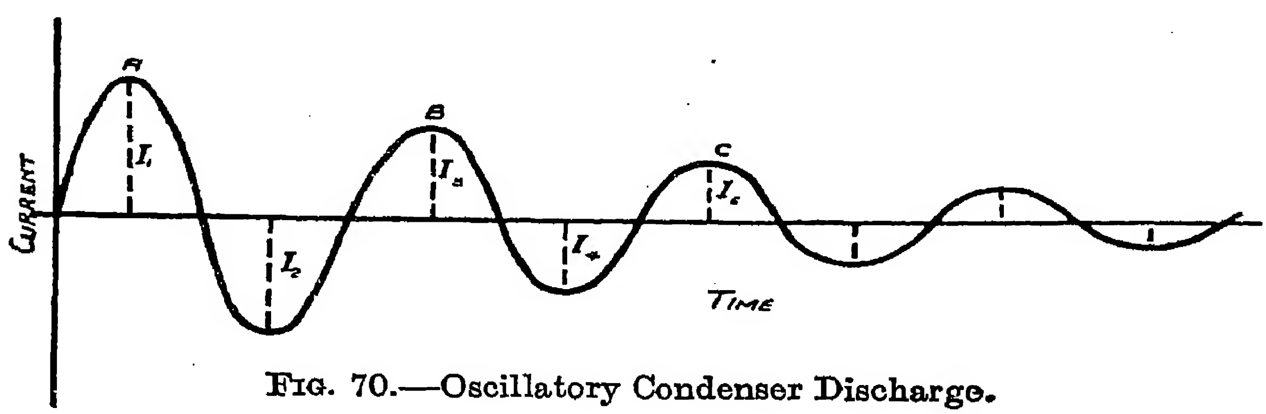


FIG. 70.—Oscillatory Condenser Discharge.

capacity, the value of the impedance—see page 84—is further modified and the equation becomes—

$$\text{Virtual amperes} = \frac{\text{Virtual volts}}{\sqrt{R^2 + \left(2\pi nL - \frac{1}{2\pi nK}\right)^2}}$$

The quantity $2\pi n$ is often abbreviated and represented by the letter p, so that the denominator may be written

$$\sqrt{R^2 + \left(Lp - \frac{1}{Kp}\right)^2}$$

That part of the total impedance due to inductance has been called "reactance," and the term "captance" has been introduced to describe the part of the impedance due to capacity. Capacity in a circuit tends to cause the current to

lead the E.M.F., and is thus seen to have the opposite effect to that produced by inductance, which has been shown to cause the current to lag behind the E.M.F.

It is plain that the current will assume a maximum value when the denominator is as small as possible. Only the resistance would have to be considered, if the values of L and K were such that the portion $\left(2\pi nL - \frac{1}{2\pi nK}\right)$ were equal to zero.

Frequency.—Again, if

$$2\pi nL - \frac{1}{2\pi nK} = 0$$

it is easily seen that

$$n = \frac{1}{2\pi\sqrt{LK}}$$

Therefore, if the last relationship between the frequency, inductance, and capacity, can be obtained, a maximum current will flow in the circuit.

In any oscillatory circuit the quantity $\frac{1}{2\pi\sqrt{LK}} = n$, where n is called the natural frequency of the circuit.

Resonance.—When an alternating or periodic E.M.F. is set up in a circuit, and the frequency of this E.M.F. is the same as the natural frequency of the circuit, a much greater current is produced than is produced if the two frequencies do not agree. This effect is said to be due to electric resonance. The frequency of the E.M.F. is said to be in tune or in syntony with the natural frequency of the circuit.

Wave Length.—It has been explained that the velocity equals the product of the wave length and the frequency. Substituting the above value for frequency we are able to obtain an equation for wave length in terms of the inductance and capacity of a circuit, as follows :—

$$\lambda = \frac{3 \times 10^{10}}{\dfrac{1}{2\pi\sqrt{KL}}}$$

where λ is reckoned in centimetres, K in farads, and L in henrys.

The units used for practical wireless telegraphic purposes are the microfarad, which is one millionth of a farad, and the microhenry, which is one millionth of a henry. When these are used as units, and λ is expressed in metres, the following equation simplifies calculations :—

$$\lambda = 1884{\cdot}96\sqrt{KL}$$

Now from this equation it can be seen that the only factors which really determine the wave length in a circuit arranged for wireless purposes (*i.e.*, without appreciable resistance) are K and L. If either of these quantities be increased a corresponding increase in wave length is effected, and if either be decreased a corresponding decrease in wave length ensues.

Clearly, the increase or decrease of wave length effected by an increase or decrease of K, or L, is not directly proportionate to such an increase. If K, or L, be doubled the wave length will only be increased in the ratio $1 : \sqrt{2}$.

An increase in K, and a proportionate decrease in L, neutralise each other, and the wave length remains the same.

The quantity $\sqrt{KL}$ is therefore called the oscillation constant.

Damping.—Fig. 70 shows the curve for an oscillating condenser discharge. The points A, B, C, etc., show the maximum value of the current in each oscillation. These values are called the amplitudes of the oscillations. The whole series of oscillations from the first with a large amplitude, to the last appreciable one, is called a train of oscillations or waves, and because the amplitude of each succeeding oscillation is smaller than that of the preceding one, such a train of oscillations is said to be *damped*. A train of oscillations of constant amplitude is said to be undamped or persistent.

Now the damping has a very important bearing on the tuning (to be discussed later), and it is necessary therefore to have some means of considering it from a mathematical point of view.

Logarithmic Decrement.—In Fig. 70 the lines I_1, I_2, I_3, etc., represent the maximum amplitudes in each successive half period, and it is found that a fixed ratio exists between any adjacent two, or that—

$$\frac{I_1}{I_2} = \frac{I_2}{I_3} = \frac{I_3}{I_4} = \frac{I_4}{I_5} \text{ etc.}$$

Also that succeeding maximum amplitudes decrease according to a logarithmic law. This can be put in the form—

$$\frac{I_1}{I_2} = \epsilon^{\delta}$$

where ϵ is the base of the Napierian system of logarithms $=2{\cdot}71828$, and δ (delta) is a constant for any particular oscillatory circuit.

Then $$\delta = \log_{\epsilon} \frac{I_1}{I_2}.$$

The constant δ is called the logarithmic decrement and is a measure of the damping in any particular circuit.

Some confusion arises from the fact that German writers define the decrement to be the Napierian logarithm of the ratio between two successive maximum amplitudes in the same direction, that is, separated by an interval of one period instead of one half-period. In the instrument designed by the Marconi Company for measuring by direct reading the decrement of a circuit, the decrement is understood to be the Napierian logarithm of the ratio between successive maximum amplitudes in opposite directions, as described above.

Number of Oscillations per Train.—Amongst other things the logarithmic decrement is useful for determining the number of oscillations in a train of waves.

Theoretically the oscillations should continue indefinitely, but in practice it may be taken for granted that when the maximum amplitude has fallen to 1 per cent. of the initial maximum, the oscillations may be considered to be damped right out.

Where m equals the number of complete oscillations in a train, and δ equals the decrement, it may be proved that

$$2m = \frac{\text{Log}_{\epsilon} \frac{I_1}{I_m} + \delta}{\delta}$$

If, as stated above, I_m has fallen to 1 per cent. of the value of I_1, the fraction $\frac{I_1}{I_m}$ becomes 100, and the above equation may be written

$$2m = \frac{\text{Log}_{\epsilon} 100 + \delta}{\delta}$$

$\text{Log}_{\epsilon}\ 100 = 4{\cdot}605$.

Therefore, provided the decrement be known, it is easy to find the number of oscillations per train from the formula

$$m = \frac{4{\cdot}605 + \delta}{2\delta}$$

If the decrement of a circuit be large, it shows that a great deal of energy is being lost either in the form of heat or by radiation. If R represents the resistance which would give an equivalent loss in the circuit, and if L is the inductance reckoned in equivalent units,

$$\delta = \frac{R}{4nL}$$

It is thus seen that where the resistance of an oscillatory circuit is comparatively great the decrement is proportionately high.

The Spark Gap.—In order to produce a powerful oscillatory discharge from a condenser, it is first necessary to charge it to a high potential. To do this the discharge circuit must be broken. It is therefore interrupted at some point where it ends usually in two metal balls, separated by an air gap. The insulation of air is very great, and consequently the condenser is not able to force a discharge current through the circuit until it has acquired a high enough potential to break down this insulation. After the first discharge in one direction, the air gap becomes conductive in proportion to the amount of electricity passing. The conductivity is also roughly inversely proportional to the length of the spark, and both these facts must be considered in fixing the size of the gap. If a condenser of small capacity be used, a small quantity will charge it to a high potential, and unless a fairly large gap be used the discharge takes the form of an arc. If a large capacity be used, a large quantity is required to charge it to a high potential, and if rapid discharge is required the gap must be a small one. With a small gap the resistance is lower,—although there is a limit to this decrease of resistance with decrease of gap,—so that an oscillating circuit of large capacity with a small spark gap is more favourable to the generation of slightly damped trains

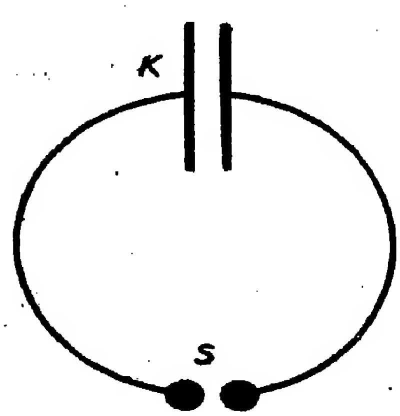


FIG. 71.—Closed Oscillatory Circuit.

of oscillations than a circuit containing a small condenser and large spark gap. Such a circuit is shown in Fig. 71, where K is a condenser and S is a spark gap. A circuit of this type does not, however, radiate very strongly. It is known as a "closed oscillatory circuit."

Plain Aerial.—The first form of transmitting apparatus consisted of a circuit of the opposite type. The condenser was of very small capacity, and as it was raised to a very high potential, the spark gap used was large.

A long vertical wire called an aerial wire, formed one side of the condenser, and the other side was supplied by the earth. As the spark gap was large, the resistance of the circuit was comparatively high, and the damping great. In addition this type of circuit, known as an "open oscillatory circuit," quickly loses its oscillatory energy by radiation. It is, therefore, a good radiator but a poor storer of energy.

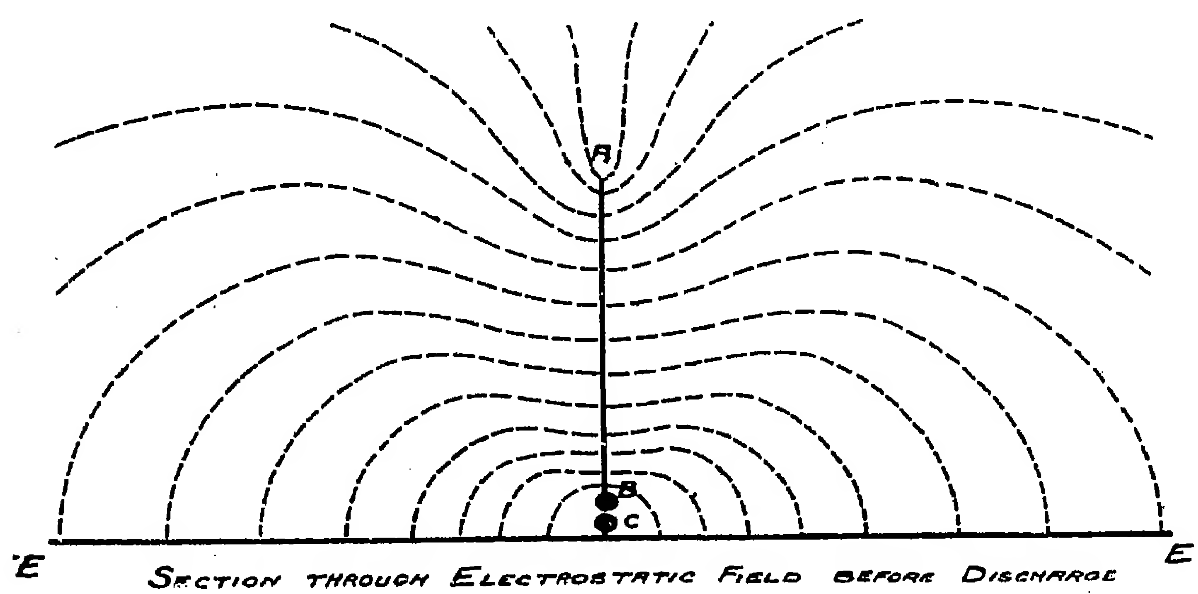
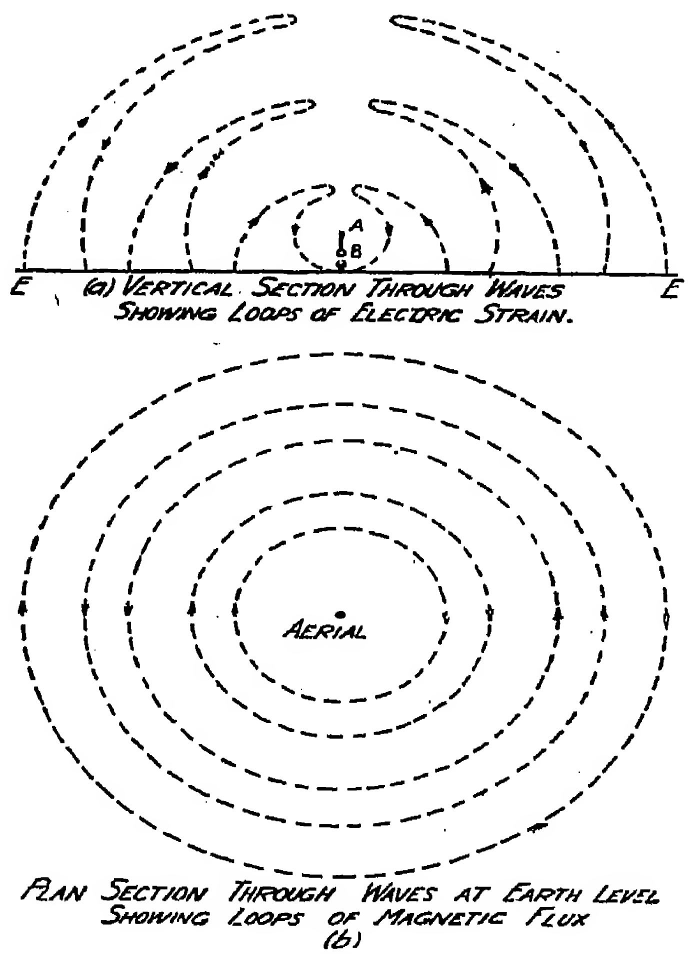


FIG. 72.—Distribution of Lines of Force round Aerial.

Fig. 72 shows this method of producing electro-magnetic waves. AB is the aerial wire and EE the earth. Some form of high voltage generator is connected across the spark gap BC. When the voltage of the aerial-earth condenser is sufficiently great to break down the insulation of the spark gap, an oscillatory discharge takes place. Before this discharge takes place the energy exists in the form of electro-static lines of force between the two halves of the condenser. Immediately the spark passes, this energy is converted into current

energy in the aerial, and ether wave energy in the space surrounding the aerial. The wave energy consists of an expanding field of periodic electric strain Fig. 73 (*a*), accompanied by a field of magnetic flux, Fig. 73 (*b*), the two fields being at right angles to each other, and to the direction in which the waves are radiated.

It is found that the wave length of this type of oscillatory circuit is between four and four and a half times the length of the aerial, but as the decrement is large this type is not used except in certain special cases.



FIGS. 73 (*a*), (*b*).—Electro-Magnetic Waves radiated from an Oscillating Aerial.

Coupling.—If part of the oscillatory circuit external to the condenser, be given the form of a coil of one or more turns, and if this coil have a second coil wound over it, or placed near it, of such a form as to be capable of carrying an oscillating current, such a current will be set up in it by induction, when the condenser discharges itself.

Such an arrangement of coils is called an oscillation transformer, and the coils are said to be inductively coupled. If the distance between the two is very small they are said to be closely coupled, and if it is great they are said to be loosely coupled. See Figs. 74 (*a*) and 74 (*b*). The coils are called respectively primary and secondary coils, and the secondary may form part of either a closed or an open circuit.

If only one coil be used between two circuits, one part of it may act as primary and another part as secondary. In such a case, where one part is common to both circuits, the circuits are said to be directly coupled and the

transformer is called an "auto-transformer," or "auto-jigger."

Direct coupling is not used in the Marconi system, but is found in the United Wireless sets, which, of course, are now under the control of the Marconi Company.

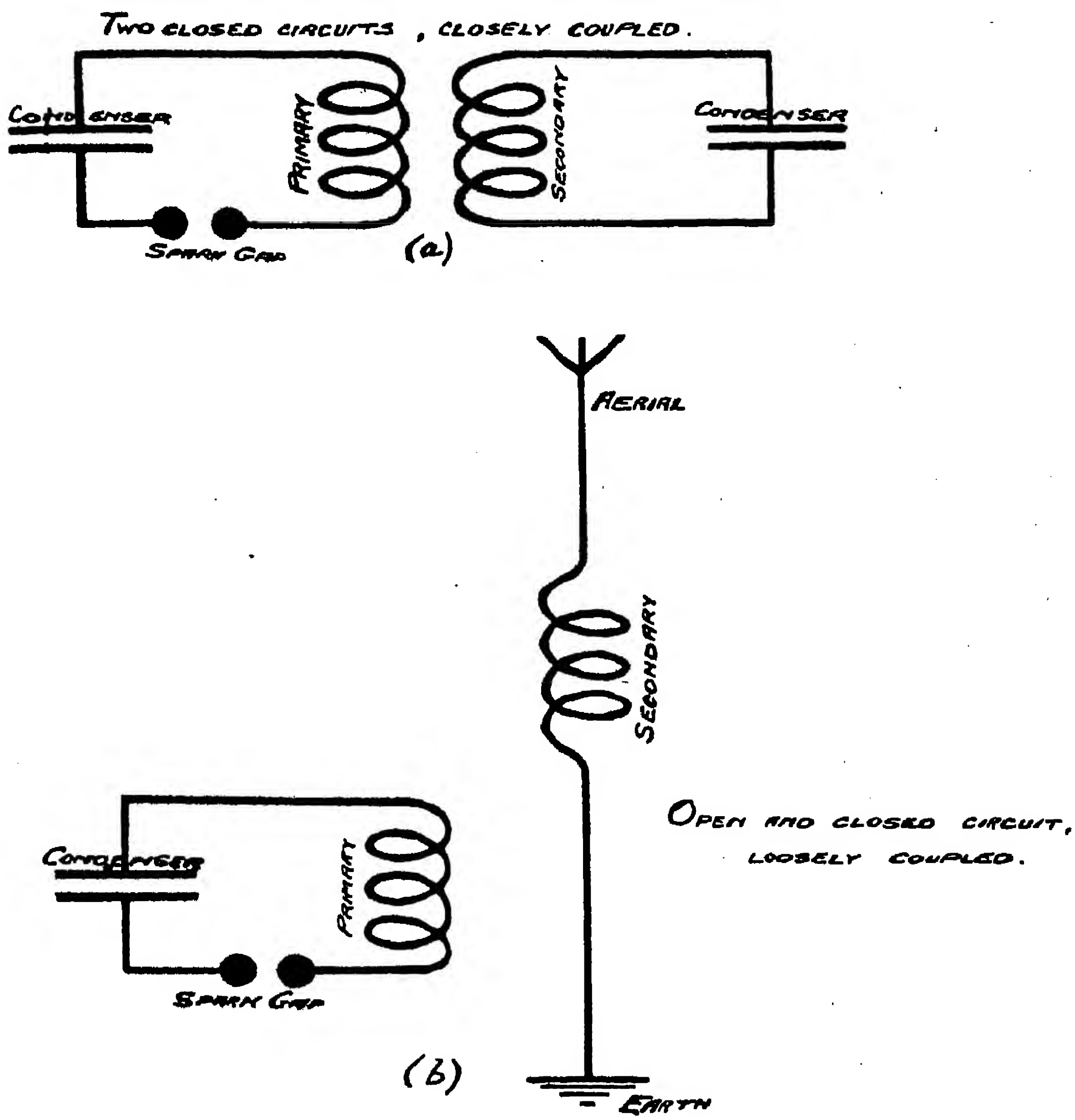


Fig. 74.—(*a*) Closely coupled Closed Circuits. (*b*) Closed and Open Circuits loosely coupled.

In the chapter on transformers it was shown that an iron core is advantageously used to increase the intensity of the field. In an oscillation transformer such a core is not used, on account of high frequency eddy-current and hysteresis loss in the iron, and the effect the core would have on the capacity of the windings. The presence of an iron core in an

oscillation transformer would give rise to the production of much heat.

If the oscillation constants of the primary and secondary circuits are equal, the current induced in the secondary is very much greater than that induced when the oscillation constants do not agree.

As the oscillation constant is simply a function of the capacity and inductance, it is seen that by introducing either a variable condenser or a variable inductance into either or both circuits, the two may be very easily put in resonance.

Again, as the strength of the current induced depends upon resonance, a measurement of the induced current affords a means of determining when such resonance has been effected. Furthermore, as the maximum current is the determining value, only a comparative measurement need be made.

Thus if a low voltage incandescent lamp be shunted across a certain part of, say, the secondary circuit, and the oscillation constant be varied by altering either the capacity or inductance of the circuit, the arrangement which gives the maximum glow of the lamp is that which places the circuits in resonance. Such a lamp is permanently connected in a standard Marconi set, and is called a tuning lamp.

Resonance Curve.—If an instrument capable of actually measuring the current be used, several readings can be taken

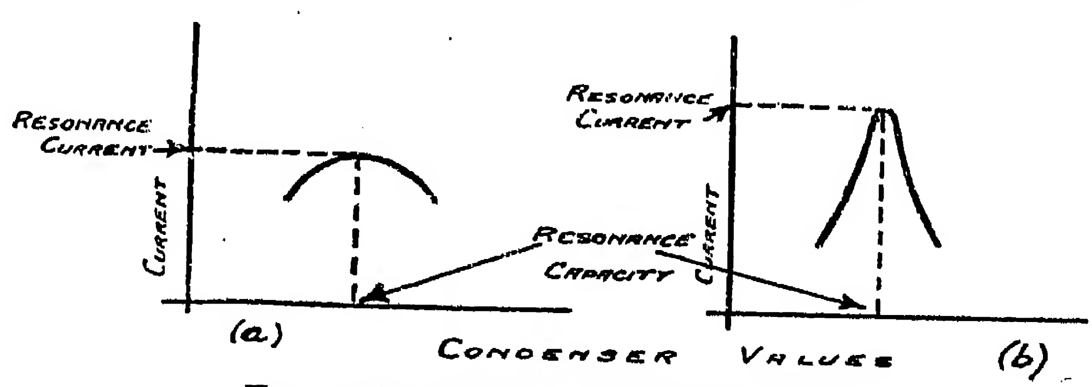


FIG. 75 (*a*) and (*b*).—Resonance Curves.

for different condenser values. A curve may be plotted with the condenser values as abscissæ and the corresponding current values as ordinates, and such a curve may take the form shown in Figs. 75 (*a*) and 75 (*b*). The peak of the curve shows the maximum current, which is called the resonance current. The frequency of the circuit corresponding to the capacity of

the condenser producing the resonance current is called the resonance frequency.

A glance at the curve shown in Fig. 75 (*b*) shows that a slight variation of the condenser,—either increasing or decreasing its value,—causes a considerable alteration in the current produced. In other words, it is seen that here exact tuning greatly increases the current, denoting small energy loss in the circuit, and consequently shows the circuit to possess a small decrement. Fig. 75 (*a*), on the contrary, shows that the current is not greatly affected by tuning, and consequently the energy loss and damping are greater.

Mutual Inductance.—If oscillations in a primary circuit inductively set up oscillations in a secondary circuit, it is logical to suppose that these secondary oscillations will in turn have an inducing effect on the primary, and so on.

The effect produced by the interaction of the primary and secondary oscillations is said to be due to the mutual inductance of the two circuits. This mutual inductance between two coils may be calculated from the following formula:—

$$M = \frac{L_1 - L_2}{4}$$

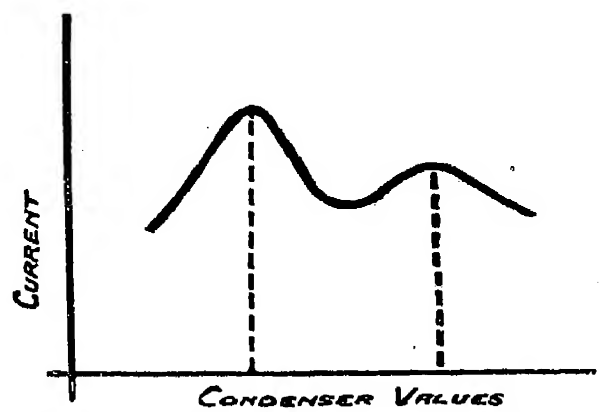


FIG. 76.—Double-humped Resonance Curve.

where M represents the mutual inductance, L_1 represents the inductance of the two coils joined in series in such a manner that the currents traverse both in the same direction, and L_2 represents the inductance of the two coils joined in series in such a manner that the current traverses them in opposite directions.

It is found, when the coupling of the two coils of an oscillation transformer is very close, that there are two values of the condenser at which a variation on either side produces a decrease in the value of the current. The curve is shown in Fig. 76, and it is seen to be double humped.

In such a case, where the two peaks are distinct and some distance apart, it is possible to measure the decrement of each set of oscillations.

When two distinct wave lengths are emitted it is clear

that the prevention of interference is more difficult. By suitably arranging the coupling, however, a position is found at which practically only one set of oscillations is detectable. If a very loose coupling be used, the mutual inductance becomes negligibly small and greater selectivity results. Radiation

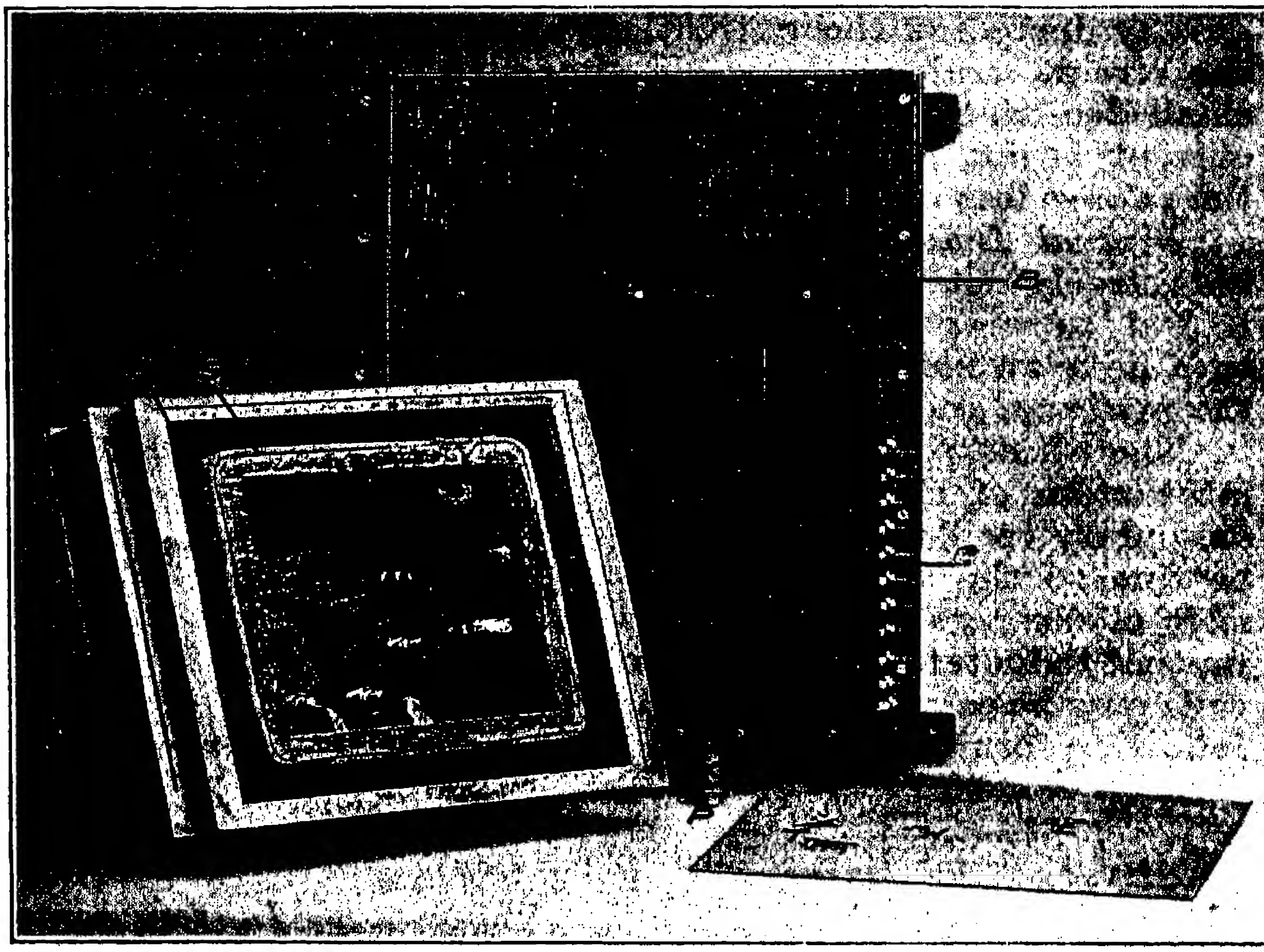


FIG. 77.—TRANSMITTING JIGGER.

B, Jigger Primary Casing.—C, Coupling Calibration.—E, Ebonite Sheet for Back of Secondary Casing.—P, Primary Terminal.—R, Rope Separator.—S, Secondary Winding.—T, Brass Thumb Screws.—W, Brass Washers.—X, Ebonite bush.

with such a very loose coupling is comparatively weak, as the amount of energy transferred to the secondary is small.

We see, therefore, that where selectivity is the great desideratum a loose coupling is necessary. Where great radiation is required a closer coupling must be adopted even at the expense of selectivity.

Coefficient of Coupling.—The coefficient of coupling is

defined as being the ratio between the mutual inductance and the square root of the product of the individual inductances, or,

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

where k represents the coefficient of coupling, M the mutual inductance, L_1 the inductance of one coil taken separately, and L_2 the inductance of the other.

Thus, in the case of a transmitting set, L_1 represents the total inductance of the primary circuit (including the leads, the jigger primary, primary inductance) and L_2 represents the total inductance of the aerial circuit (including aerial, aerial tuning inductance, and jigger secondary).

As coupling has an effect on the decrements and frequencies of the oscillations, a true measurement of coupling must be based on some relationship introducing decrement in addition to mutual and individual inductance.

The inclusion of decrements makes the calculation somewhat involved, but as the decrements are so small they can be neglected in the type of coupling used in a standard set.

Percentage or Degree of Coupling.—Coupling is usually reckoned as a percentage of the maximum. Theoretically the closest coupling would be unity, but this is impossible in practice, as inductance in a circuit is not confined to the coupling coil but is spread throughout the circuit. If by calculation or experiment the coupling is found to be 0·1, for instance, as this is one-tenth of unity, this coupling may be expressed as a 10 per cent. coupling.

The coupling is most conveniently found from the following formula :—

$$k = \frac{\lambda_1^2 - \lambda_2^2}{\lambda_1^2 + \lambda_2^2}$$

where k is the coupling, and λ_1 and λ_2 the lengths of the two waves emitted ; and if λ_0 is the wave-length of each circuit (primary and secondary) separately,

$$\lambda_1 = \lambda_0 \sqrt{1 + k} \text{ giving the longer wave,}$$

$$\lambda_2 = \lambda_0 \sqrt{1 - k} \text{ giving the shorter wave.}$$

CHAPTER II.

The Receiving Circuit.

Receiving circuit—Telephone—Detectors—Magnetic detector—Tuning of receiving circuit—Coupled receiving circuits—Resonance curves—Flattening effect of resistance in receiving circuit—Method of increasing selectivity of receiving circuit—Valve detector—Rectifying effect—Resistance of telephones—Crystal detectors—Carborundum—Action of a crystal detector.

The receiving circuit may be looked upon as being the secondary circuit in an extremely loosely coupled oscillation transformer of which the transmitting circuit is the primary.

Take two leyden jars. Arrange to spark one of them, allowing the connections from the inside and outside coatings to have sufficient length to give the resulting oscillatory circuit appreciable inductance. The other leyden jar should have the inner and outer coatings connected through a slider bar, as shown in Fig. 78. Another lead, as short as possible and enclosing a minimum area with the jar, should be brought from the inner coating to within a short sparking distance of the outer coating at B. Then it will be found that when a spark discharge takes place at A in the first circuit, under certain conditions a discharge will also take place at B in the second circuit. These conditions are obtained when the oscillation constants of the two circuits are made to agree, and this can be done by adjusting the slider in the B circuit. The B spark can be produced when the two jars are some distance apart, and is due to the electro-magnetic waves radiating from the first circuit impinging on the second circuit, and setting up corresponding oscillations in it. These oscillations through resonance increase in amplitude until finally the charge in the condenser overflows in the form of a spark. If the distance between the two circuits is great, the energy in the second

one is not sufficient to break down the spark gap and no discernible oscillations are set up in the circuit.

The amount of energy in the receiving circuit depends to a great extent on the surface presented to the oncoming waves. It has been explained that an oscillatory circuit consisting of an earthed elevated conductor is a good radiator. At the same time it will be seen that such a conductor presents a great surface on which waves may impinge. Thus an elevated conductor may be used at a wireless station for both transmission and reception purposes. In wireless stations of low power the same conductor or aerial is used for both purposes,

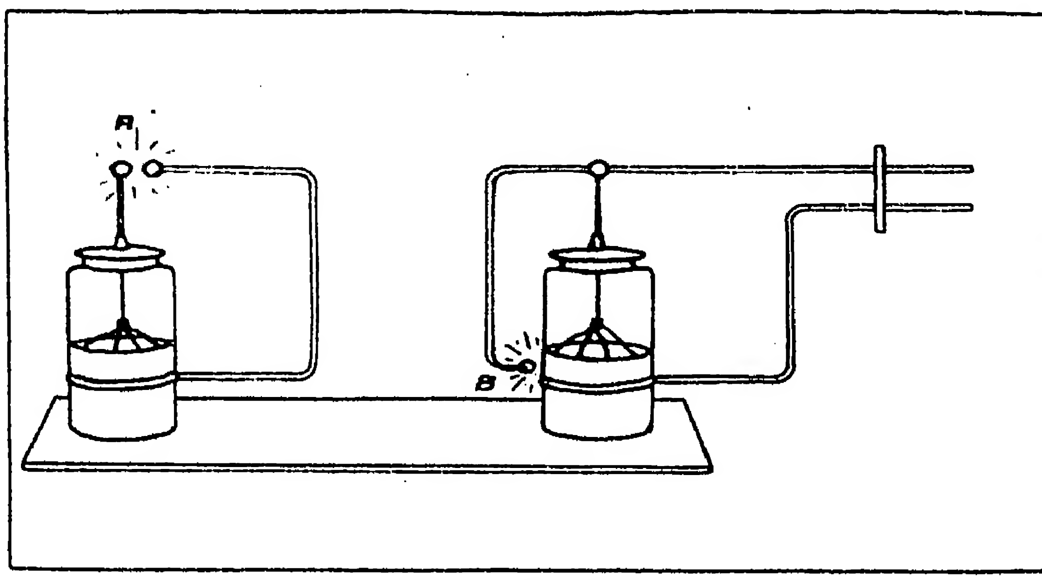


FIG. 78.—Experiment in Resonance.

but where large power is used it is found that separate transmitting and receiving aerials are required.

If the oscillation constant of such a conductor be the same as that of a distant similar conductor, oscillations in the latter produce electro-magnetic waves which set up oscillatory currents in the former. These oscillatory currents are so very weak, however, that their detection can only be effected by the insertion in the circuit of very delicate apparatus.

The Telephone.—Now the telephone is one of the most sensitive pieces of electrical apparatus known, but as its action is electro-magnetic and dependent upon the variation of the magnetisation of an iron core, the reactance of the telephone coils being very large, would prevent the oscillatory currents from passing. Also the telephone diaphragm is unable to keep pace with the extremely rapid

changes in direction of an oscillating current, and in order to use the telephone as a receiver the oscillating currents must be converted into intermittent unidirectional currents.

Even presuming, however, that the telephone could vibrate in time with the oscillating currents, the vibrations would be at such an extremely rapid rate that they would not be detected as sound by the human ear, which in many cases is unable to hear the comparatively low note of a bat's cry.

The Magnetic Detector.—Various devices are adopted for rendering the oscillating currents detectable. The best known method is by means of an instrument known as a magnetic detector. In this instrument a band of stranded soft iron wire is kept moving round two insulated pulleys. This band passes in front of the poles of two permanent horseshoe magnets. Now the particles of iron become small magnets under the influence of the lines of force, and as the band is moving it has the power to drag the lines of force along in the direction of its motion. As the particles of iron pass from the influence of a north pole to that of a south pole the direction of magnetism is changed. But this change in magnetism does not take place in time with the change in the force producing it. That is to say, the particles do not change their magnetism until some time after they have passed the point where the influence of the opposite pole is being exerted. If an oscillating current be passed through a coil of wire wound round the moving band where it passes in front of the magnets it has the effect of causing the lag in magnetism to disappear. Such a coil is wound on a small glass tube as shown in Fig. 79, and the ends of this coil are connected to the elevated conductor and earth respectively.

A second coil of a much greater number of turns is wound over the first and a pair of telephones is connected to its extremities. When the transmitting station sends out a train of waves, oscillating currents are set up in the receiving aerial, which pass through the primary coil and cause a sudden change in the state of magnetisation of the moving iron band. This change induces a current in the secondary, which passes through the coils of the telephone and causes a vibration of the diaphragm. Thus just as long as sparks take place at the sending station, corresponding changes will be taking place in the magnetism of the moving band and the diaphragm will

be kept in continuous vibration. If the sparks be made for long and short periods representing dashes and dots of the

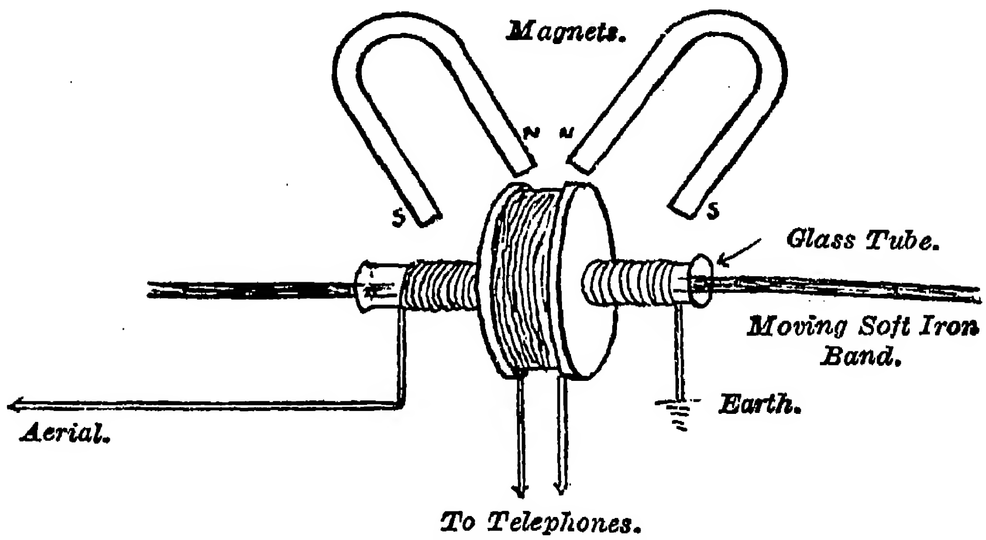


FIG. 79.—Diagram of Magnetic Detector.

Morse code, sounds of corresponding duration are heard in the telephones.

Tuning.—A receiving circuit consisting only of an aerial with such a magnetic detector connected between it and the earth would not, however, be of very much use in actual practice. It is necessary to also introduce some means of varying the oscillation constant of the circuit in order to place it in resonance with the frequencies of any particular transmitting station with which it may be desired to communicate. The natural frequency of an aerial depends on its size and shape, which determines its capacity and inductance. A decrease in its capacity may be effected by placing another capacity in series with it. Whereas its inductance cannot be conveniently decreased, it may be

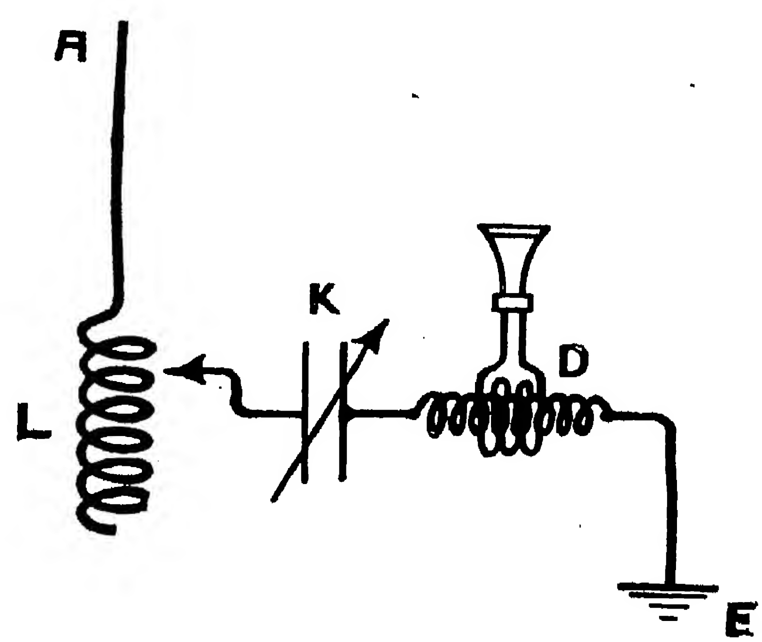


FIG. 80.—Simple Receiving Circuit.

increased by adding inductance in series. Thus, by placing a variable inductance and a variable condenser in series with the aerial all the necessary means for either increasing or decreasing the oscillation constant within certain limits are provided. Fig. 80 shows such a circuit. A, represents the aerial, K, a variable condenser, L, a variable inductance, D, the magnetic detector, and E, the earth.

Harmonics.—Now, such a circuit would not only respond to oscillations of its own frequency, although such oscillations would produce the maximum effect in it, oscillations with frequencies of one-third, one-fifth, or one-seventh of its natural frequency known as harmonics could also be set up in it. Again, if the transmitted wave has sufficient strength, it may cause the receiving aerial circuit to start oscillating by impulsing it, although the transmitted wave may be neither the fundamental nor a harmonic of the aerial.

Oscillations of all kinds are more readily set up in an open circuit of the aerial type than in a closed circuit. Consequently the primary of an oscillation transformer is often made part of the open receiving circuit, while the secondary of the transformer forms part of a closed circuit containing the receiving apparatus.

Coupled Receiving Circuits.—This closed circuit, not responding so well to the harmonics of its fundamental frequency, and being more difficult to impulse by out-of-tune waves, is then better adapted to the elimination of all waves other than the fundamental, the wave required. Such an arrangement of two circuits is shown in Fig. 81. The second circuit must, of course, be supplied with means of tuning it to the open circuit, and a variable condenser is used for this purpose.

As in the transmitting arrangement already described, the coupling between the primary and secondary of the transformer has a tendency to produce oscillations of two frequencies, one below and one above the frequency of the received wave. Thus, if the coupling be a close one, two adjustments of the variable condenser—corresponding to the two peaks of a double-humped resonance curve—can be found by trial, which give a pronounced increase in signals compared with any other adjustment. The transmitted wave is often a double-humped wave, and the strongest signals are produced when the coupling of the receiver accommodates these two

humps by being made the same as the coupling of the transmitter. Therefore the circuits are so arranged as to admit of variable coupling.

When "standing by" to receive from a station sending on a wave of unknown length, a close coupling is used to make the receiver responsive through a wide range of wave lengths. As soon as communication is established the coupling is loosened in order to render the receiver responsive through a narrow range of wave lengths, and thus avoid interference from other transmitting stations.

This refers to receivers other than the Multiple Tuner, described on page 178, which obtains a wide range of responsiveness on "stand bi," by switching the detector direct into the aerial circuit (see page 181).

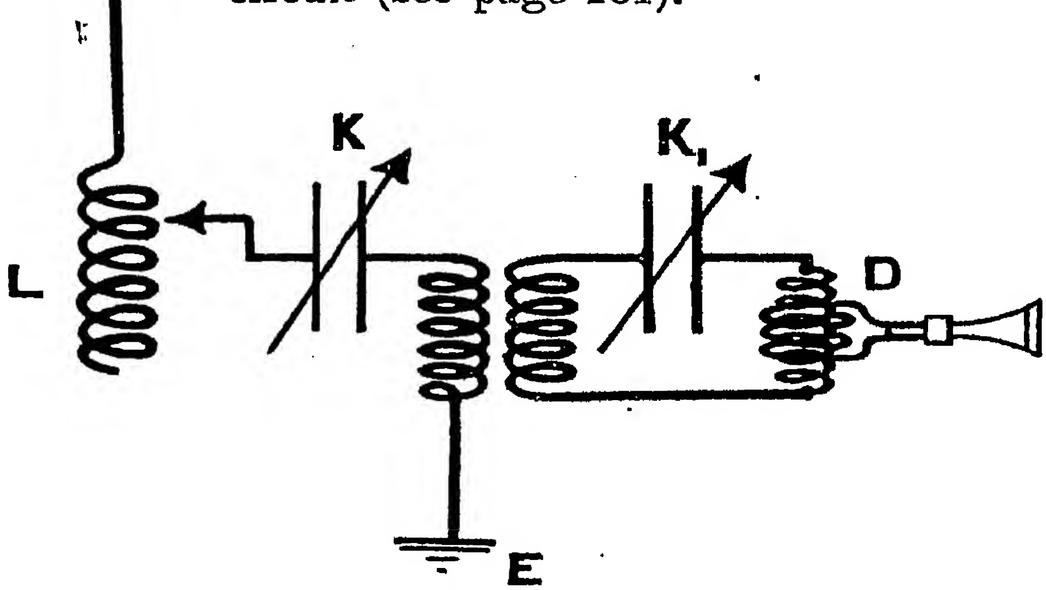


FIG. 81.—Coupled Receiving Circuits.

When a circuit is said to be tuned for the reception of a certain wave length, it is understood that the adjustment is such that stronger signals are obtained on that wave-length than on any other. It is found, however, that waves of a slightly different length, either longer or shorter, will produce signals in the receiver, which signals are weaker than those from the tuned wave.

We can, therefore, plot a curve showing the relationship between the strength of the received signals and the respective wave lengths. The peak of this curve, of course, denotes the strength of the signals produced by the wave for the reception of which the circuit is in tune.

If the peak rises sharply, as in Fig. 75 (*b*), it indicates that the circuit responds only slightly to waves of a different length, but if the curve is a flat one, as in Fig. 75 (*a*), it shows that the circuit is responsive to wave lengths varying through a wide range.

Intermediate Receiving Circuit.—It has been said that a closed circuit is better adapted to the elimination of all waves other than the one required. An extra intermediate oscillating circuit is therefore very often interposed between the aerial circuit and a third circuit containing the detector.

The intermediate circuit contains two coils, one of which

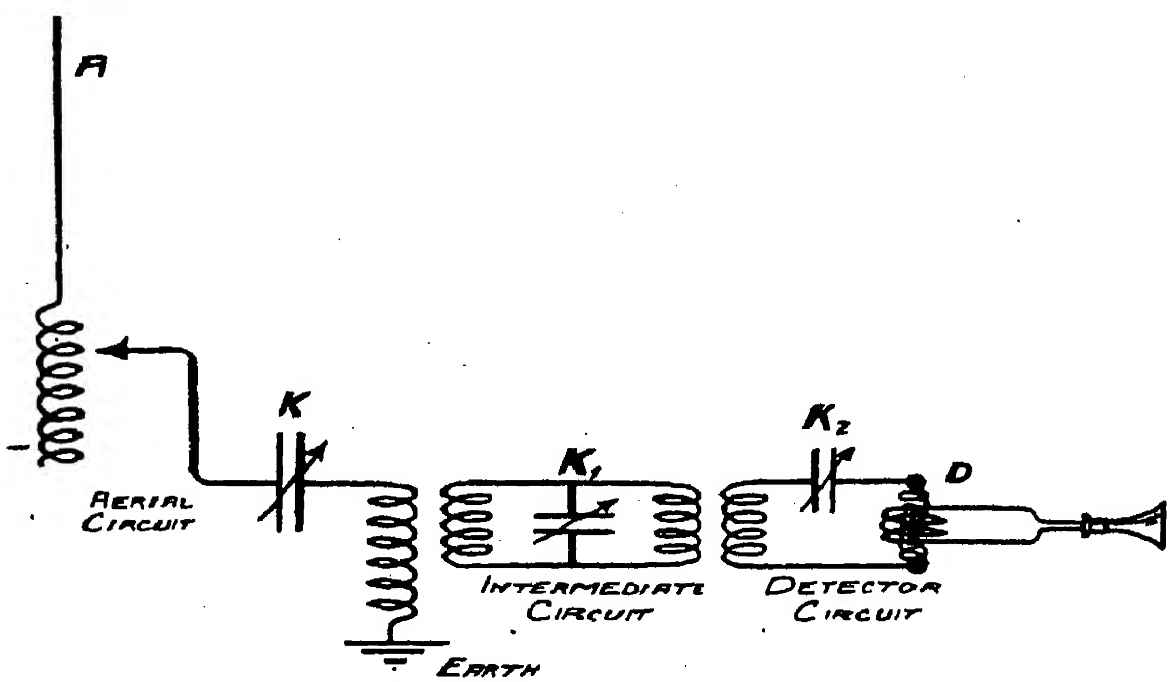


FIG. 82.—Receiving Circuits of Multiple Tuner.

acts as a secondary to the primary in the aerial circuit, while the other acts as a primary to the secondary contained in the detector circuit. This arrangement is shown in Fig. 82. The condenser by means of which the intermediate circuit is tuned is placed in parallel with the coils ; it may be regarded as the common part of two circuits which are electrostatically coupled. The variable capacities and inductances for the three circuits are all contained in an instrument called a multiple tuner. The actual tuner contains other parts, which will be dealt with later when describing the instrument in detail.

The Valve Detector.—Another detector, which is found to be more sensitive than the magnetic detector, is known as a Fleming valve rectifier. This consists of a tungsten or carbon

filament lamp in which a cylindrical metal sheath surrounds the filament. It is found that when the filament is incandescent the space between it and the sheath is conductive in one direction. If such a lamp be placed in an oscillating circuit the oscillations are rectified into intermittent uni-directional currents capable of actuating a telephone. Negative electricity

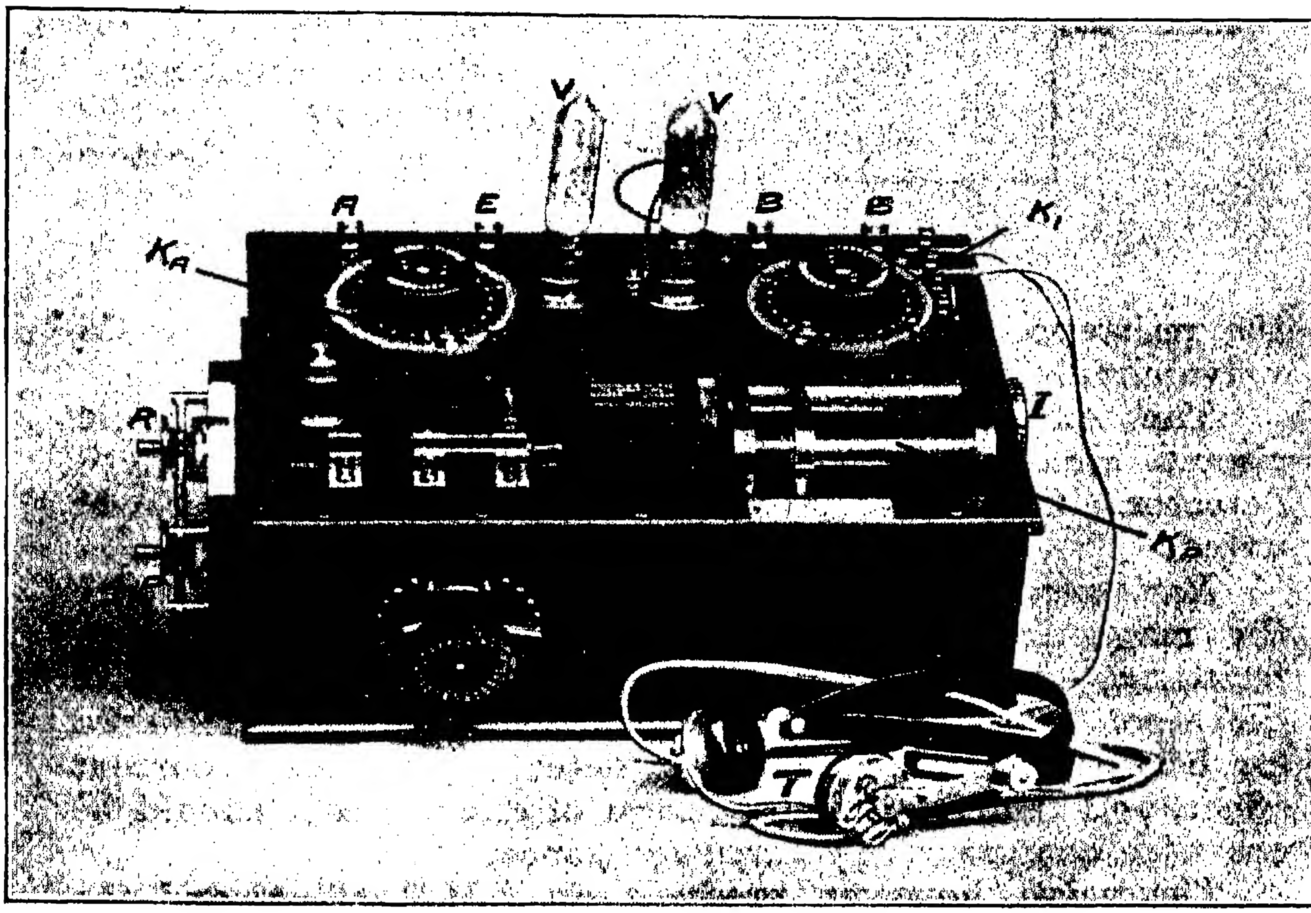


FIG. 83.—VALVE TUNER.

A, Aerial Terminal.—B, Valve Battery Terminals.—E, Earth Terminal.—I, Intensifier Handle.—KA, Aerial Condenser.—KI, Intermediate Condenser.—KD, Detector Condenser.—P, Potentiometer.—R, Valve Resistance.—T, High Resistance Telephones.—V, 4-Volt Valves.

is said to pass from the glowing filament to the sheath, and consequently one end of the oscillating circuit is connected to the negative lamp lead and the other to the sheath. The intensity of the glow of the filament has a certain effect on the strength of the rectified current, and consequently a variable resistance is used in connection with the battery from which the current producing incandescence is taken.

It is also found that if an E.M.F. be applied to the valve

circuit a more sensitive condition is obtained. A high resistance is joined across the battery supplying current to the valve, and a moving contact on it is connected to the telephones. This resistance is called a potentiometer, because any desired difference of potential within the range of the battery can be obtained between the sliding contact and one end of the resistance fixed to the battery. The arrangement of the valve circuit is shown in Fig. 84.

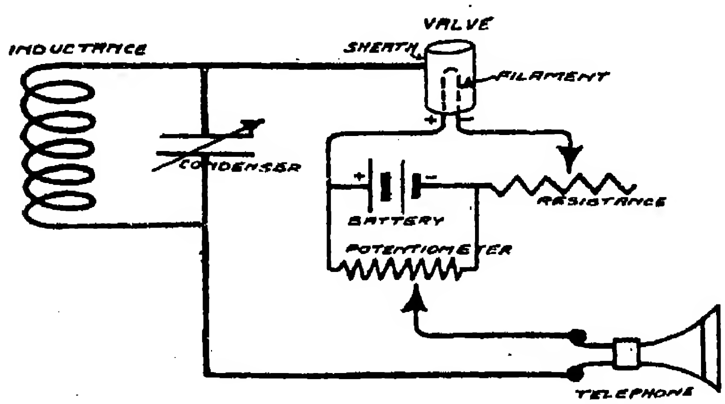


FIG. 84.—Valve Detector Circuit.

The valve detector is used in connection with various circuits similar to those employed when using the magnetic detector. One important difference should, however, be noted.

Resistance of Telephones.—The telephones used with the magnetic detector are wound to a comparatively low resistance—namely, 140 ohms. This is the same as that of the secondary coil, an equality in resistance being required for best results. The magnetic detector produces a current effect, and therefore the best form of circuit for it should be one with comparatively small resistance.

The valve, however, produces an E.M.F. effect, and the resistance of the telephones can therefore be made fairly large without appreciably reducing the current in the detector circuit. More turns on the telephone coils result in this case in an increase of ampère turns notwithstanding the increase of resistance. The telephones used with a valve receiver may be wound to a resistance as high as 8,000 ohms, but a more usual figure is about two or three thousand ohms. If a telephone transformer is used in conjunction with low resistance telephones, a similar increase of ampère turns can be effected. Such a transformer would be of the step-down type, the primary winding containing a great number of turns compared with the secondary, so that a current of lower E.M.F. but greater ampèrage is obtained.

At one time the windings of an ordinary ten-inch induction

coil were used for this purpose, but a special telephone transformer occupying much less space and weighing considerably less is now employed.

Crystal Detectors.—Many natural minerals, such as zincite, chalco-pyrites, silicon, molybdenite, galena, bornite, tellurium, to name a few, when properly used, have the power to rectify weak alternating currents. In some minerals the crystals are thin flakes, in others they have distinct facets, but in every case in order that a crystal should rectify, a good broad contact must be made at one place on it and a constricted point contact at another. The rectification takes place at the point contact. For a flake crystal such as molybdenite, a metal point or the point of another crystal is used to make an active contact.

For what we may call a facet crystal, an active contact is made by placing one of the edges or sharp points against a metal plate, or the surface of another crystal.

Frequently, however, facet crystals are so closely agglomerated that they have to be treated as if they were flake crystals and a suitable rectifying place sought on them with a metal point.

The qualities looked for in a good commercial crystal detector are—that it should rectify with very small changes of potential, it should be constant and reliable in operation, and unaffected by atmospheric conditions. That it should resist mechanical shock, and should not be too friable. Its rectification should not be destroyed by atmospheric discharges nor by the inductive effect of a neighbouring transmitting set. One cannot hope to obtain a crystal perfect in all these respects, but carborundum, a chemical product of pronounced crystalline structure, composed of silica and carbon, is easily the best all-round crystal rectifier, and has therefore been adopted by the Marconi Company for general use.

Carborundum varies very considerably in composition and properties. It is produced by fusion, and therefore blocks of the substance present two characteristic surfaces ; one which has been attached to the furnace wall and has a fused appearance, the other which is composed of irregular masses of large crystals formed at the end of the fusing process. Crystals for rectifying purposes are generally found halfway through the thickness of the block.

The hard grey quality frequently covered with pure graphite

gives crystals of high resistance and low sensitivity. The highly coloured carborundum exhibited in show cases, on the other hand, is too soft. It breaks easily, has a low resistance, and is a bad rectifier. Such crystals can, however, be used in wavemeters. Carborundum suitable for receivers has an intermediate character. Although colour is no reliable indication of quality, the best crystals are generally green or bluish-grey. After careful selection by a rectification test, the chips of carborundum which rectify negatively are inset in solder in brass cups, leaving the active points exposed. Positively rectifying crystals could also be used if required.

The characteristics of crystal detectors in general vary over a wide range. With some, the low voltage of the induced H.F. signal current is quite sufficient to cause useful rectification; with others, it is necessary to apply to them a certain

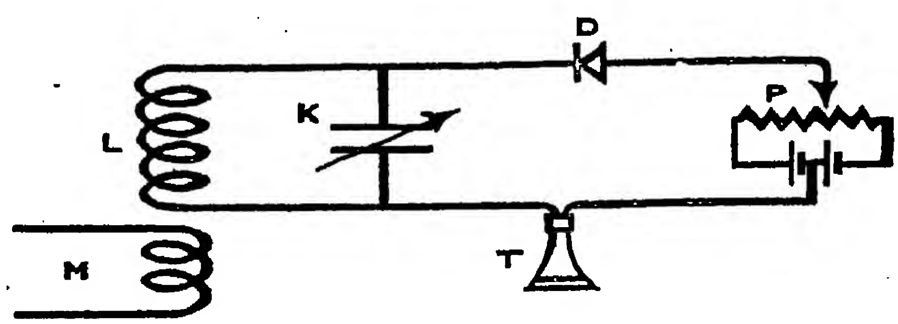


FIG. 85.—Crystal Detector Circuit.

steady voltage before they reach a state at which small signal voltages can cause the telephone to respond. The effective resistance of one kind of crystal to the rectified current may be a thousand ohms, but with another kind the resistance may reach a hundred thousand ohms. Some crystals have a pronounced capacity effect, but with others it is almost negligible. It follows that the best form of detector circuit will depend on the class of crystal used.

Detector circuits may be broadly divided into two main types; one, in which the capacity of the resonance circuit which impulses the detector is fairly appreciable, say, of the order ·001 mfd.—which seems to be best for crystals of zincite, chalco-pyrites, molybdenite, etc., the other type in which the capacity of the resonance circuit is very small, say of the order ·0001 mfd.—which seems to be best for carborundum.

A typical detector circuit is shown in Fig. 85. K is a

variable condenser which together with the fixed inductance L resonates to the H.F. current in the inducing coil M. A crystal detector D, in series with a telephone T, is brought to a condition of maximum signal sensitivity by the potentiometer P, and is connected across the condenser so as to be affected by the H.F. potential due to the received signals. A rectified intermittent current passes through the crystal and the telephone, and the sound of the dots and the dashes heard in the telephone has a pitch corresponding to the frequency of the transmitting spark.

The Action of a Crystal Detector.—This will now be considered a little more in detail. If a potential difference is established between two places on a crystal detector, so that one place is negative and the other positive, it is found that—as in the case of a valve detector —the amount of current which will pass depends on which of these two places is positive and which negative. If the potential is applied in one direction an appreciable current may flow, if the direction is reversed the current may be altogether stopped. The crystal is said to conduct "asymmetrically" or "unilaterally." In general practice a carborundum crystal is considered good enough for use if the ratio of the currents in the two directions on the application of 2 volts is 40 to 1.

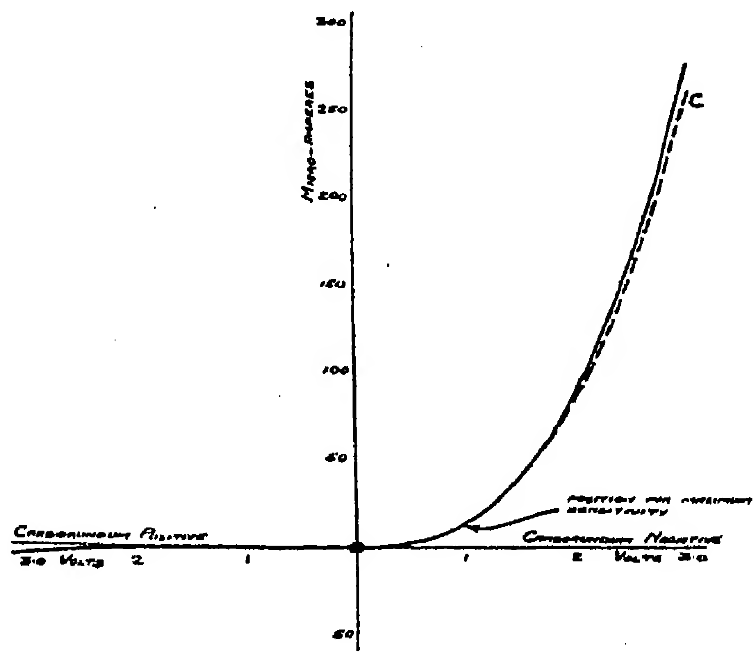


FIG. 86.—Characteristic of Carborundum Detector.

Fig. 86 shows the voltage-current curve—the "characteristic"—of a specimen carborundum detector. The values of current have been measured for different values of steady voltage applied from the crystal to the steel plate—marked "carborundum positive"—to the left of zero, and from the steel plate to the crystal—marked "carborundum negative"—to the right of zero.

The first point to notice is that the characteristic is not a straight line, the value of $\frac{\text{applied E.M.F.}}{\text{current}}$ or the apparent resistance, alters from point to point on the curve. The crystal therefore does not obey Ohm's Law.

The next point to notice is that for potentials up to 1·5 volts a current can be obtained when the carborundum is negative, but no current when it is positive—there is complete rectification.

For potentials above 1·5 volts the negative current is much larger than the positive current—there is partial rectification. If the positive characteristic is subtracted from the negative characteristic we get the dotted curve C.

This new curve shows us that if an alternating potential is applied to the crystal of any value up to 3 volts where the curve ends, no steady potential being applied at the same time, the strength of the rectified current will increase with the potential increase. Also the slope of the curve shows us that the rate at which the rectified current increases rises steadily as far as the last value on the curve.

But the potential due to the high frequency signal current is very small; it can never approach the high values which are shown to give most rectification. Suppose the signal potential reaches ·01 volt. When this is applied direct to the plain carborundum crystal, the resulting current is negligibly small and there is no apparent rectification.

But it may be possible to assist the crystal by applying to it a fixed potential in the best direction. Let the fixed potential be 1 volt. Then the ·01 volt will be continuously added and subtracted from it by the high frequency signal potential, and there will be a variation in current as indicated by the slope—otherwise called *the differential*—of the curve C at 1 volt.

But suppose the slope is a straight line. Then the current increase must equal the current decrease; the mean current through the telephone will be the same as if there were no signals and the telephone will give no sound. The arrangement will be comparable to that state of the crystal which gives no rectification. If the telephone is to respond, the mean current under the influence of signals must be greater or less than the current due to the steady potential. This will occur when the slope of the characteristic at the working potential,—in the

present case 1 volt,—is different below to what it is above this potential. In other words, the characteristic must show a *change of slope*.

The strength of the telephone signal, then, depends on the *rate of change of slope*. This relation is given by the 2*nd differential* or curve C. The position on the characteristic at which the value of applied steady potential brings the crystal to the condition which gives largest variations in telephone current on the application of a small alternating E.M.F.—which is therefore the position of greatest sensitivity—is found to be in the sharp bend of the curve, where the rate of change of slope is a maximum. To determine this position by calculation is a tedious matter, but in practice it can be found with ease.

A battery voltage known to be more than is required for the purpose, is applied to the crystal through a potentiometer, and by simply moving the potentiometer slider, the potential on the crystal can be quickly varied until it reaches that value which gives strongest signals in the telephone.

The small increment of rectified current resulting from each wave received, adds itself to the current increments due to all the other waves in the same wave-train, to build up the resultant current which acts on the telephone to produce one beat of a signal note, the complete note being produced by the added effect of all the wave-trains.

PART III.

CHAPTER I.

1½ K.W. Sets.

The standard 1½ k.w. set—Transmitting circuits—Direct current circuit—Main switch—Starter—Field regulator—Converter —Low frequency primary circuit—A.C. switchboard—Low frequency iron core inductance—Manipulating key—Magnetic key (single)—Transformer primary—High tension circuit—Transformer secondary—Air core choke coils—Main condenser—Closed oscillatory circuit—Plain discharger—High frequency sliding inductance—Transmitting jigger primary—Short wave adjustments—The 1½ k.w. disc discharger set—24 stud disc discharger—Main condenser, new type—1½ k.w. Transformer, closed magnetic circuit—Air core chokes, porcelain formers—Radiating circuit—Jigger secondary—Aerial tuning inductance—Earth arrester spark gap—Tuning lamp—Short wave condenser—Receiving circuit—Magnetic detector—Multiple tuner—Crystal receiver, type 20—Disc condenser—Billi condenser—Telephone condenser—Telephones—Short circuiting device —Adjustment of receiving circuit—Measurement of received waves—Measurement of transmitted waves—Double coil set.

The student is now in a position to understand the working of the various parts of a standard Marconi 1½ k.w. set. This set is most frequently used on board ship, and, of course, depends for its current upon the ship's dynamo. Two main leads are brought into the operating room and connected to a double pole knife switch. From this switch onwards the care and management of the wireless apparatus lies entirely in the operator's hands, and for this reason it is intended to

give a full description of each part in the order in which it appears in the different circuits.

TRANSMITTING APPARATUS.—THE DIRECT CURRENT CIRCUIT.—The first circuit to be considered is that used in connection with the driving of a rotary converter. This circuit may be said to contain four pieces of apparatus—the main switch, the starter, the field regulator, and the converter.

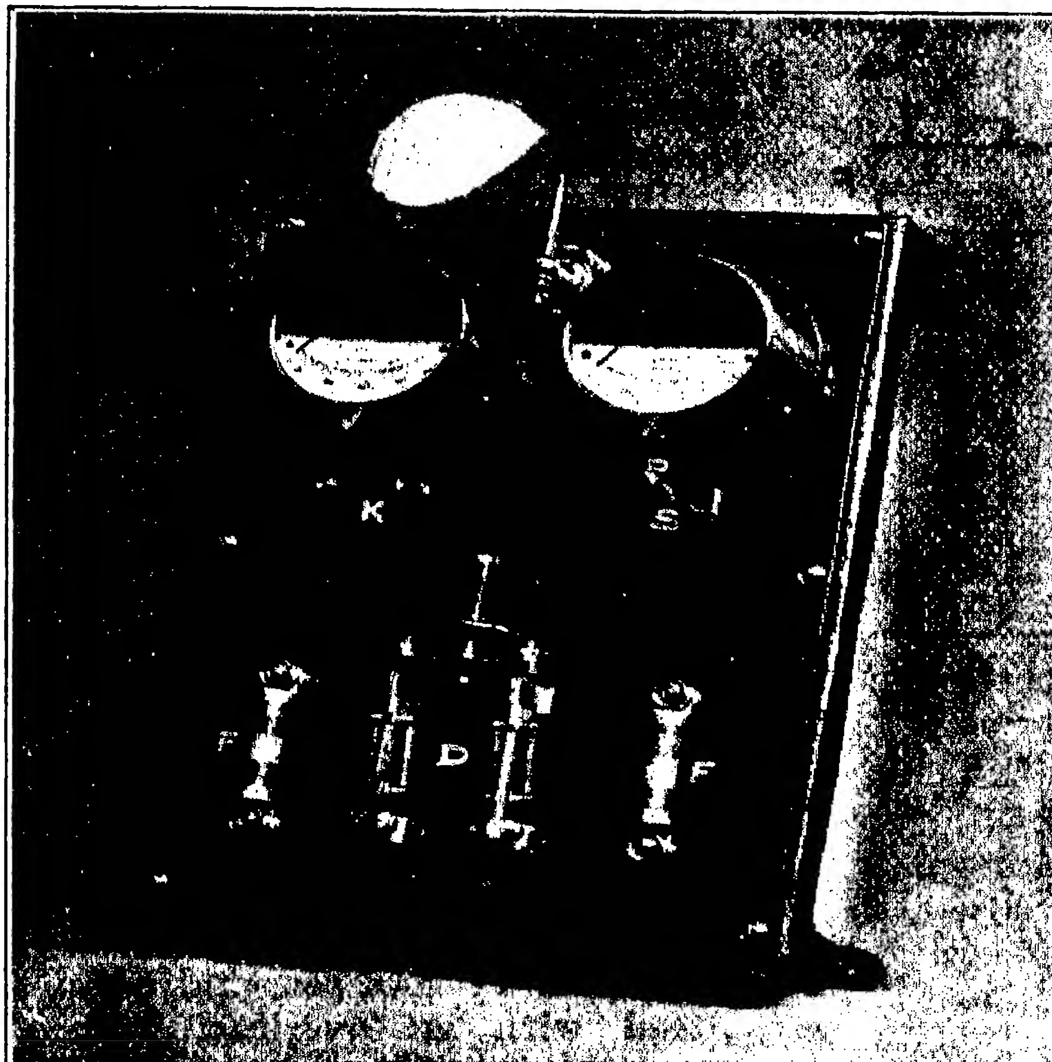


FIG. 87.—1½ K.W. A.C. SWITCHBOARD.

A, Ammeter.—D, Double-pole knife switch.—F, Cartridge fuses.—K, Voltmeter key.—L, Pilot lamp.—P, Ammeter short circuiting plug.—S, Short circuiting plug socket. —V, Voltmeter.

The main switch is of dimensions large enough to enable it to carry a current of fifty ampères. By dividing each switch arm into two parts and connecting the two parts by means of a spring a means of breaking the circuit quickly is obtained.

Fig. 88 shows a side elevation of the switch. A and B are the two parts referred to, and S is a helical spring joining them at A and B. The complete double-pole switch is hinged at E, and when it is closed each switch arm makes a knife contact into a socket F.

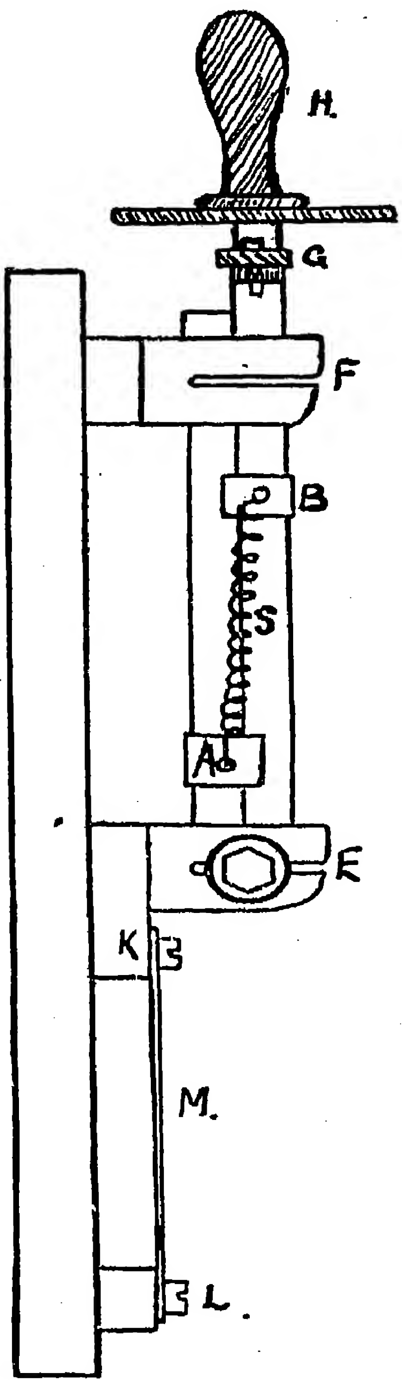


FIG. 88.—Double-Pole Knife Switch.

The two arms B, are tied together by an insulating bridge piece G, to which the handle H is fixed. When the circuit is being broken the part B comes away from the socket F, leaving the second part A at rest in the socket until the tension on the spring S is sufficient to pull it out suddenly. The brass block K, at the base of the switch, is supplied with a nut and washer in order that a fuse wire, M, may be attached between it and the screw L, from which point one of the leads to the converter circuit is taken.

The Starter.—The starter consists of a series of resistance coils, mounted in a cast-iron case on the front of which is a slate face fitted with brass contact studs, no-volt release, starting handle and (in some cases) an overload release. Tappings from the series of resistance coils are brought to the studs on the face of the starter. Fig. 89 shows the connections of a starter which is generally used in a 1½ k.w. set, and which is not fitted with an overload release. The three terminals marked J, F, and A, are connected to "line," "field," and "armature" respectively. An internal connection connects the terminal L with the moving arm or starting handle H, which carries a small soft-iron armature, S, on one side of it. The under side of the arm H is supplied with a spring contact brush of laminated copper, and the first stud is bevelled in order that this brush may ride easily on to it. A light spring fitted with a carbon contact forms an extension

of the brush, on which it first makes circuit with the active studs. The carbon therefore takes any sparking which may occur and thus saves the main contacts from burning. The first active stud is connected by means of a short straight wire, W, to one end of the no-volt release winding N, from the other end of which a connection is taken to the terminal F. As is seen from the diagram, the first stud is also connected to one end of the series of resistance coils, the other end being connected directly to the terminal A. The connection at N between the first stud and the winding of the no-volt release is also in metallic connection with the soft iron frame or core on which the wire is wound.

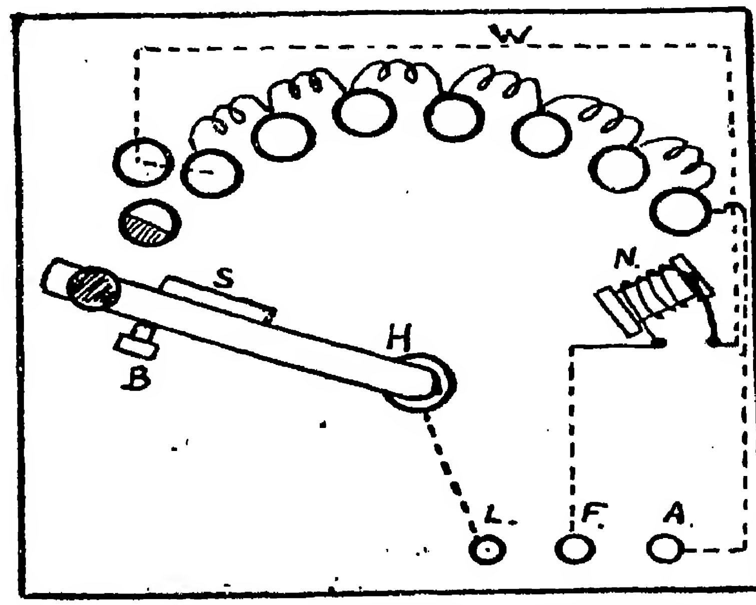


FIG. 89.—Connections of Starter.

Fig. 90 shows the starting handle. C is the carbon contact mentioned above, and S the main contact spring brush.

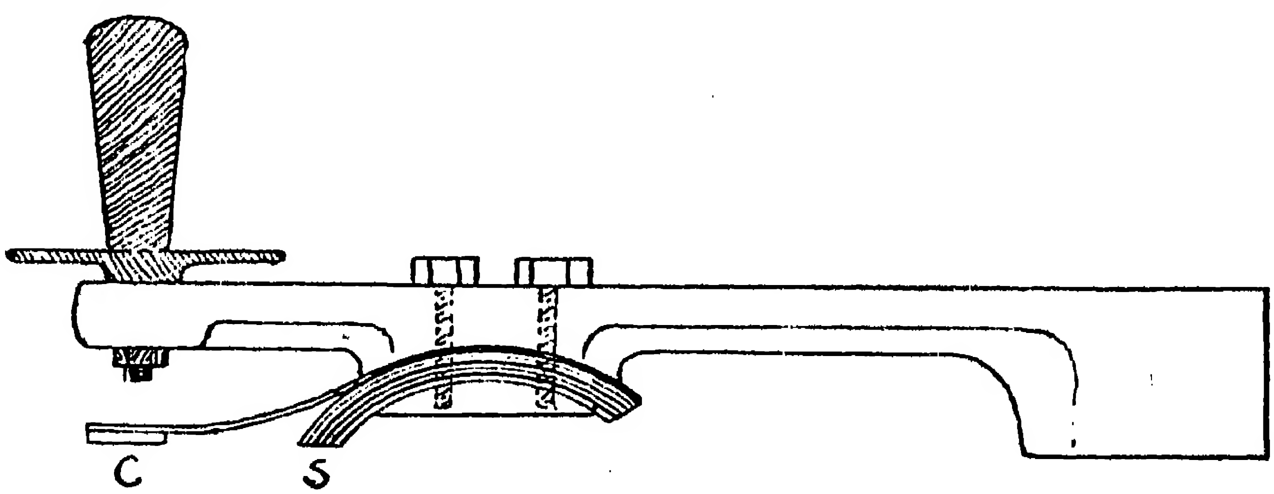


FIG. 90.—Starter Handle.

The handle is kept in the "off" position against the buffer B, Fig. 89, by means of a helical spring fitted in the boss at the pivot end. The tension of this spring may be regulated to a strength suitable to the power of the electro-magnet

of the no-load release. An idea of how this adjustment is made can be obtained from Fig. 91.

F is the slate face of the starter, P the pivot pin, and H the boss of the starting handle. A spring S is fitted over the pin, one end of it being fixed in a small socket K, the other end in a socket B, in a brass collar C. The right adjustment of spring tension is obtained by rotating C the desired amount, and then fixing it by means of the screw L, which passes through one of four holes in the collar C into a screwed hole in the handle, a tommy-hole M being provided for the purpose of this adjustment. The fitting is completed by a nut N, set so as to allow the handle an easy movement, and fixed at that setting by the split pin T.

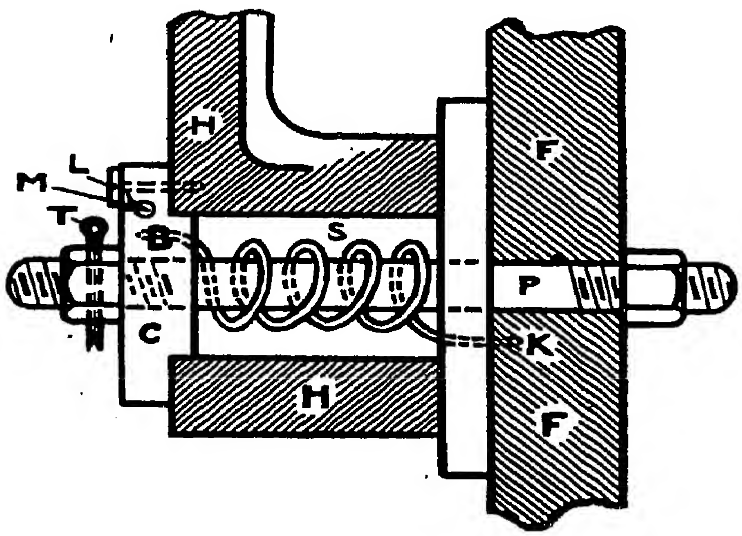


FIG. 91.—Antagonistic Spring in Starter Handle.

The Field Regulator.—The field regulator is somewhat similar in appearance to the starter. It consists of a series of resistance coils, connected to a set of brass studs fixed on the face of a slate slab. The first and last studs are respectively marked "in" and "out." Two terminals are supplied at the base of the slate face, the left-hand terminal being connected internally to the pivoted end of the regulating handle, and the right-hand terminal being connected internally to the last

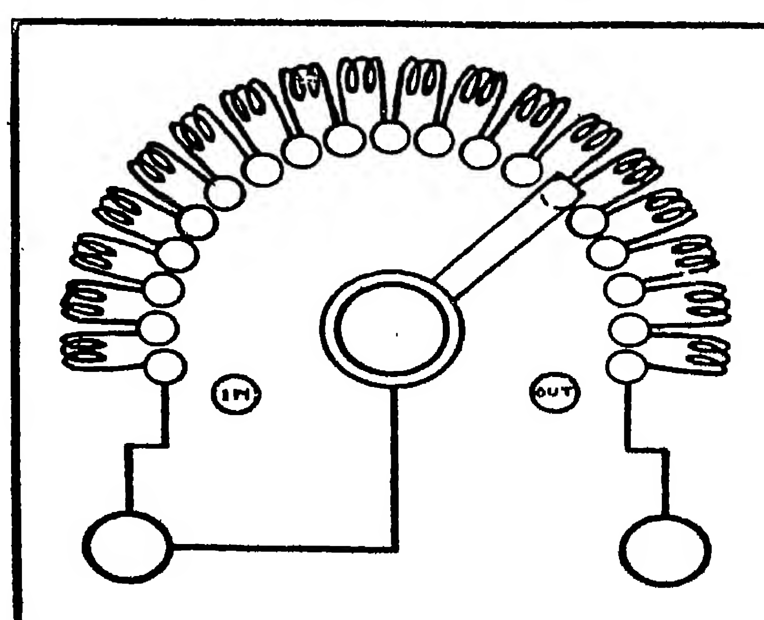


FIG. 92.—Field Regulator.

stud marked "out." The left-hand terminal is also connected to the "in" end of the resistance, to prevent the field circuit being broken as the result of a bad contact made by the regulating handle. The handle is of a much lighter nature than that of the starter: the brush contact has only to carry small field currents, and as it must be capable of being left permanently on any stud, the handle—unlike that of the starter—is not fitted with a spring return. Fig. 92 shows the connections of the field regulator.

The Rotary Converter.—The machine itself possesses a cast-iron magnet fitted with four poles, arranged with like poles opposite each other as shown in Fig. 93. The action of the machine can be understood by considering it from the following simple standpoint. The armature coils are wound at an angle of ninety degrees, and each of them can be looked upon as a polarising coil. Thus in Fig. 93 the armature is shown with a certain polarity marked on each of four equal parts of its periphery. Then it may be said that while N_1 is attracting S, S_1 is repelling it, both forces tending to drive the armature in the direction shown by the arrows. A consideration of each separate set of poles will show that this force is continuously in the same direction.

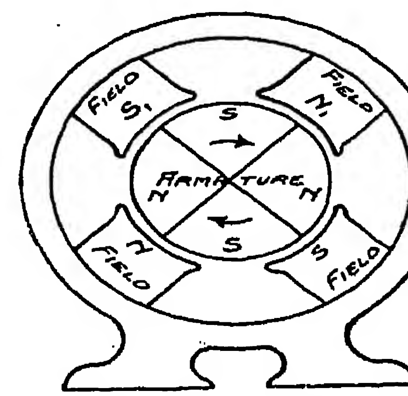


FIG. 93.—Action of Motor.

Brush Adjustment.—The armature, as previously stated, is fitted with a commutator at one end and two slip rings at the other. The direct current is supplied to the armature through four carbon brushes connected in pairs, as in Fig. 94. It is found that these brushes must rest in one particular position on the commutator, otherwise sparking between the brushes and the copper segments ensues, with the result that the commutator gets burnt and develops what are known technically as "flats," so that in a short space of time it has to be re-turned on a lathe. The exact position is found by experiment, and is usually a little distance in advance of the line joining the centres of two opposite field magnets, as in Fig. 94. This position is generally fixed by the makers, but provision is made for adjusting the brushes. The brushes are placed in brush holders, which are fixed on supports

attached to a movable end-plate in the frame of the machine.

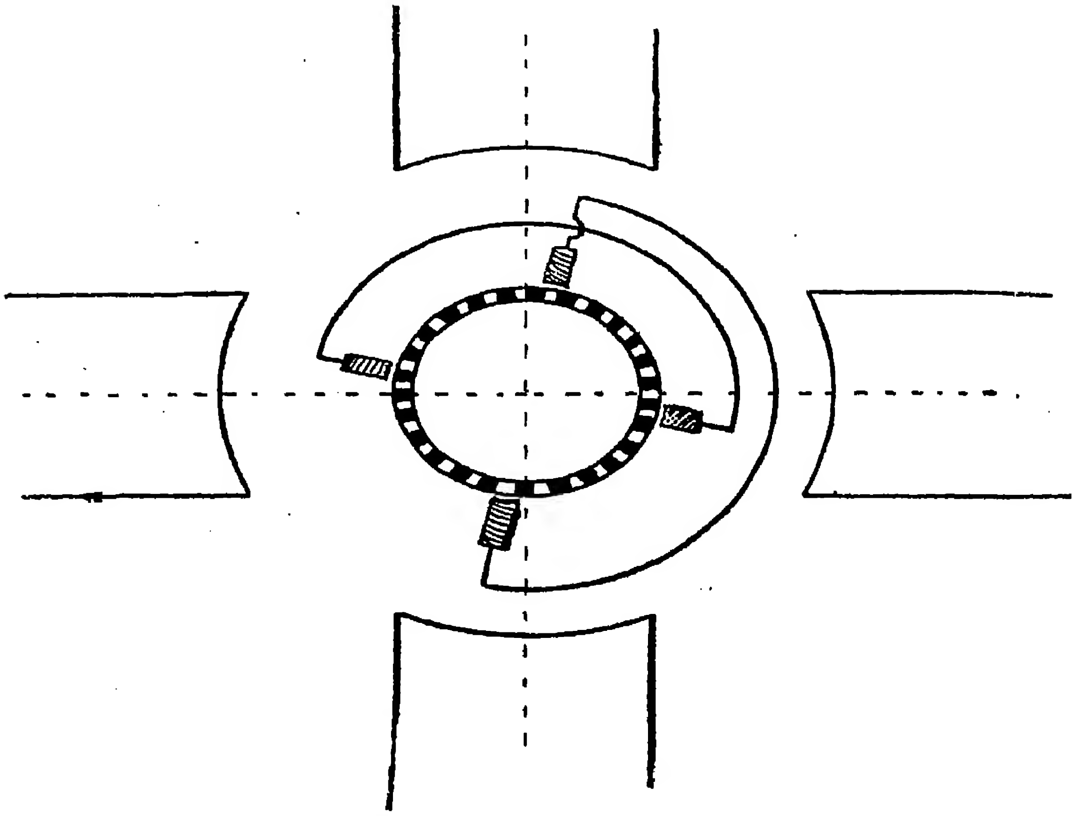


FIG. 94.—Connections and Disposition of D.C. Brushes.

This plate is so arranged that it is capable of rotation through

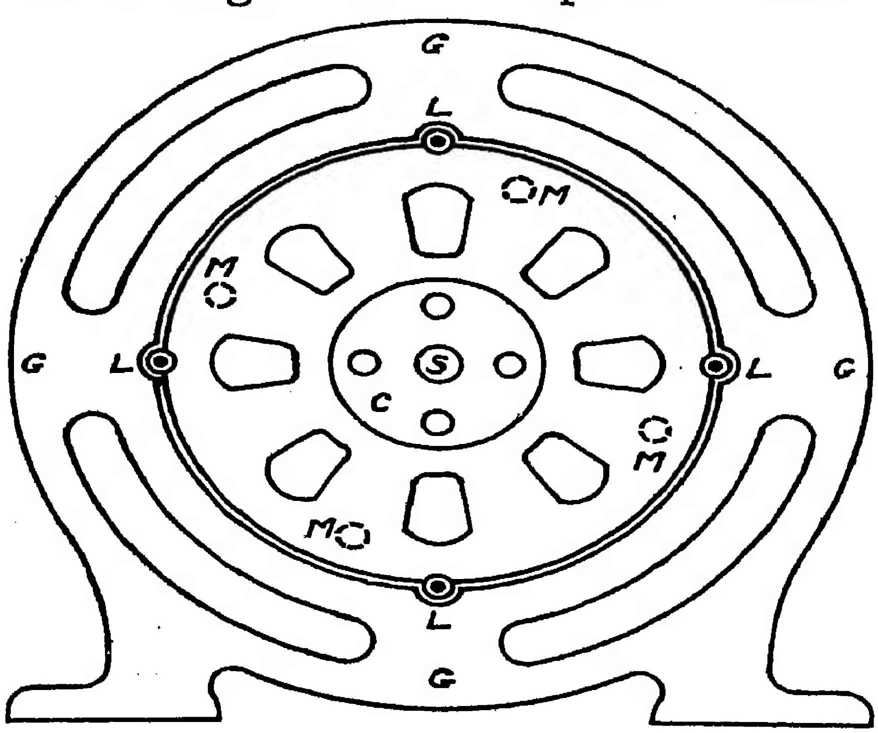


FIG. 95.—Diagram illustrating Brush Adjustment.

an angle large enough for all possible brush adjustments.

Fig. 95 represents a view of the machine at the commutator end. S is the end of the shaft, C is the outer cover of the ball bearing, F the movable end plate which carries the brush holder supports shown at M. In order to rotate F,—and therefore to alter the position of the brushes,—the clamping bolts L must first be slackened. When the right brush position has been found, the operator must not forget to tighten up the bolts L again.

Brush-holder.—A diagram of the brush-holder is shown in Fig. 96.

C is a cast brass clamp, through which the bolt B passes, and

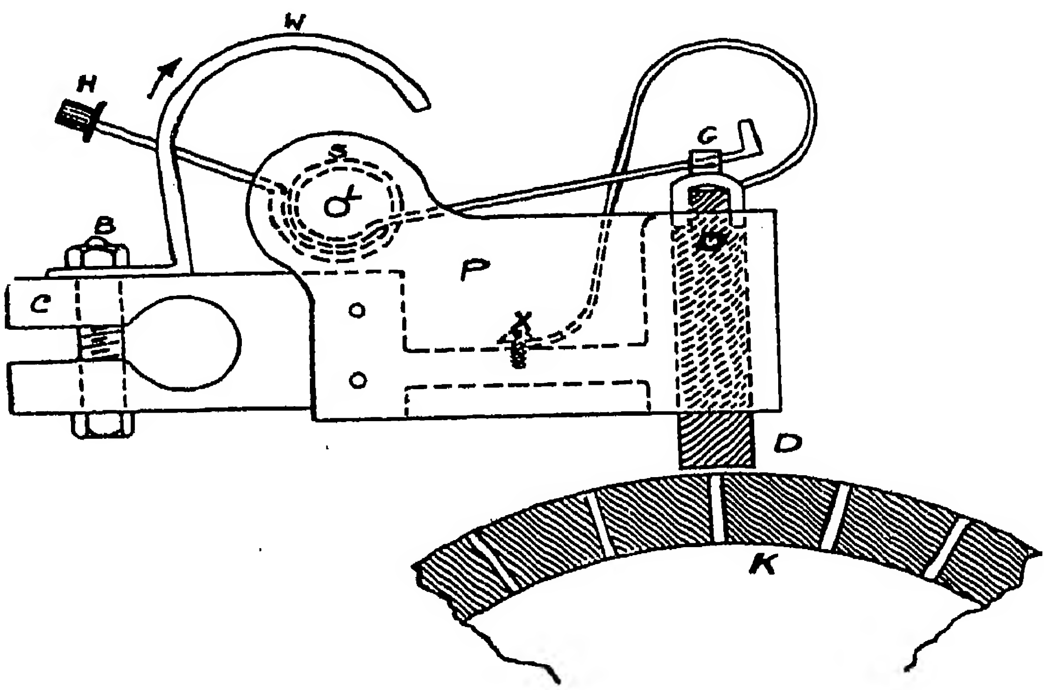


FIG. 96.—Brush Holder.

is used for clamping the holder to one of the supports previously mentioned. Two plates, P, are riveted to this clamp, and at the point L between these plates a pin carrying the spring is fixed. One end of this spring is fitted with a wooden handle, H, and the other end catches under a copper hook, G, which is permanently fixed to the carbon brush, D. The handle H may be moved in the direction shown by the arrow, and this movement puts tension on the spring S, thus causing the brush to make contact with the commutator K. The straight part of the spring fitted with the handle, moves through a toothed slot in the curved piece of brass shown at W, and by engaging in any tooth it is held in any particular position. The carbon brush D is supported

at right angles to the commutator. It requires to be an easy fit up and down in the holder, but to have a minimum clearance in all other directions. It is electrically connected to the holder by means of the flexible connection, shown partly in continuous and partly in dotted line, held in position by the screw X. The commutator is wider than the brushes, and consequently in order to ensure equal wearing of the whole surface the brushes are "staggered." Fig. 97 illustrates what is meant by this expression. A and B are diametrically opposite each other on the commutator, both being nearer the side marked L. The brush C is diametrically opposite another one, which cannot be shown in the drawing, but which we will call D. The brushes C and D are fixed nearer the side R of the commutator. Thus a part of the commutator which can be represented by the line XY is being evenly worn by the brushes.

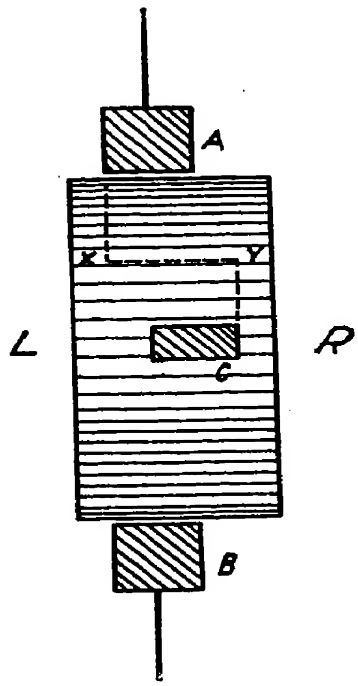


FIG. 97.—Position of Brushes on Commutator.

Slip-rings.—Two brass rings are mounted on, and carefully insulated from, the shaft at the end remote from the commutator. These rings are also insulated from each other by means of a fibre ring. Four carbon brushes are used in connection with these slip rings, being connected in pairs in a similar manner to those used on the commutator. One pair of connected brushes is used in connection with each ring. This end of the shaft overhangs the machine, and it is convenient to arrange a rocker to carry the brush-holders on the outside of the frame. This rocker is shown in Fig. 98. It is cast in two halves, A and B, the two portions being clamped together round a part of the main casting by means of the screws C and D. At E, F, G, and H insulated standards are fixed to which the brush-holders may be clamped. If the dotted

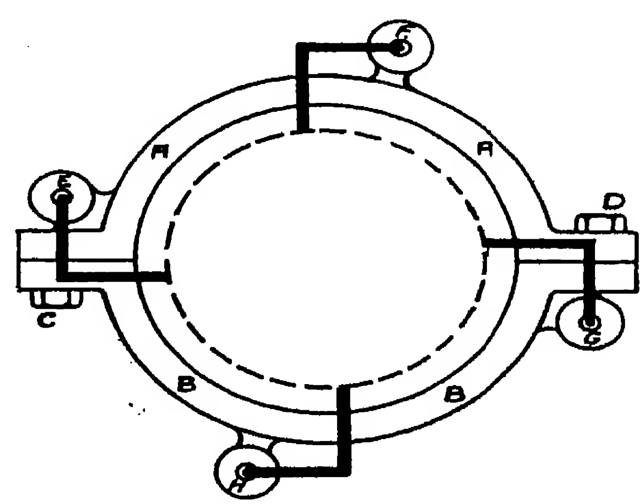


FIG. 98.—A.C. Brush Rocker.

circle represents the outside of the slip rings, the position of the brush-holders and brushes is approximately given by the straight lines terminating on the circle. It is usual to fix this rocker so that the clamping lugs are horizontal. The position of these brushes with respect to the field magnets is immaterial, and if any sparking takes place it may be put down to dirty or uneven contact.

Connections.—The connections are shown in Fig. 100 (*a*), where it will be seen that one end of the field winding is connected to one of the D.C. brushes, the other end being continued through an insulated hole in the frame of the machine marked "field." A connection from the brush which is connected to the field winding is brought through another insulated hole in the frame marked "line," while a connection from the remaining brush, is brought through a third hole in the frame marked "armature."

Reading from left to right the holes through which the cable connections pass are marked respectively "armature," "field," and "line."

A connection is taken from the cable marked "line" to one pole of the main switch, and another from the cable marked "armature" to the terminal similarly marked on the starter. The cable marked "field" is connected to the terminal under the stud marked "out" on the field regulator, —that is to say, the right-hand terminal.

A connection is taken from the "in" terminal of the field regulator to the terminal marked "field" on the starter, and finally a connection is made between the terminal marked "line" on the starter, to the other side of the main switch.

A complete diagram of the direct current connections is given in Fig. 99. The connections marked A, B, and C are made with 7/16 I.R.V.B. (india-rubber vulcanised braided) lead-sheathed cable, and the connections marked D, E, are made with 3/22 I.R.V.B. lead-sheathed cable.

The machine is built for a normal voltage of from 80 to 110 volts direct current, but is used on voltages as low as 60, and as high as 130, with satisfactory results. The normal speed is 1,500 to 1,800 revolutions per minute, and the variation obtainable by means of the field regulator is approximately 10 per cent. down and up.

Starting.—After seeing that the handle of the starter

is in the "off" position, and that the field resistance is all out, the main switch may be closed and the handle H of the starter pulled over on to the first stud. The field magnets are now excited by the passage of the full

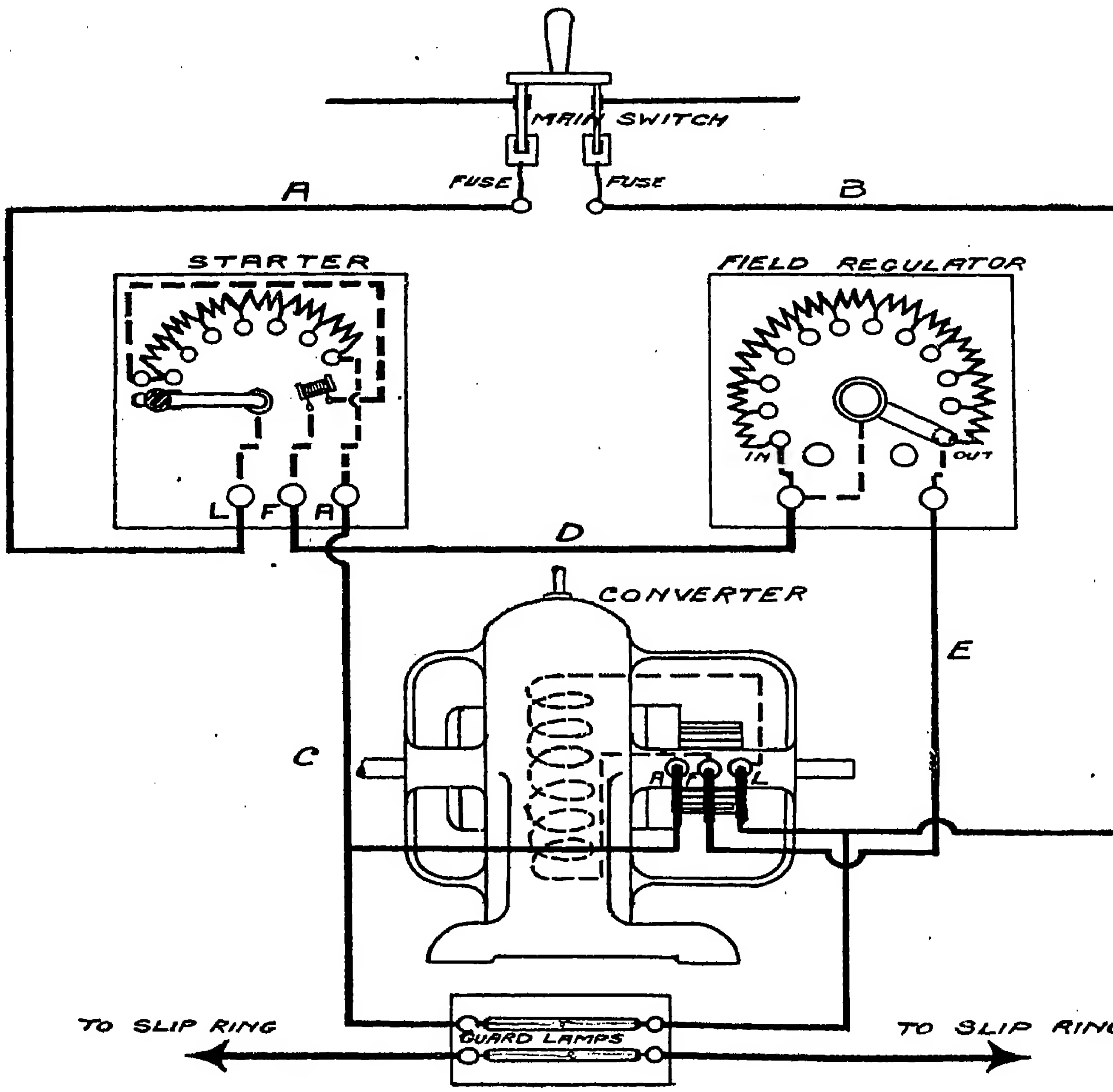


FIG. 99.—1½-K.W. Converter Connections.

current available, as there is no resistance in the field circuit.

The current through the armature windings has to pass through the total resistance in the starter, but since the armature is not rotating there is no back E.M.F. to oppose that of the mains, so that a considerable current (about 1½

times the full working current) passes through the armature, reacts with the field, and starts the armature rotating. When the machine has acquired a constant speed with the handle on the first stop, the handle may be carried forward on to the next one. This operation may be carried on, only passing from one stop to the next after the machine has come to a constant speed, until the handle comes to rest against the no-volt release, when it will be held there by the magnetic pull of the latter, provided the tension of the antagonistic spring in the handle is not too great. At this point, the resistance,—which is gradually put into the field circuit as it is taken out of the armature circuit,—is once more cut out of circuit altogether, because, as previously stated, the magnet winding and the connection to the first stop are both connected to the metal bobbin of the no-volt release. The machine is now found to be running at a constant steady speed. If a greater speed be desired, it is necessary to put in a little extra field resistance, or if a slower speed be required, the removal of a little field resistance has the desired effect, these operations being effected by turning the handle of the field regulator either towards "in," or "out," as the case may be.

Direction of Rotation.—The direction of rotation of the armature may be changed by changing over the leads marked AA and LL in Fig. 100 (*a*), so that they are arranged as in Fig. 100 (*b*), shown now as LA and AL. The connection between the end of the field winding marked F, must also be removed from the top left-hand brush,—looking at the machine from the commutator end,—and be connected to the bottom left-hand brush. The necessary alterations are shown as dotted lines in the second figure.

CARE OF MACHINE.—*Lubrication.*—Brass cups are fitted over the bearings, which must be kept full of grease. Occasionally the cups must be taken off and as much of the old grease as it is possible to get at must be removed, the cup being refilled with clean grease. The cap of the cup must also be filled before replacing. Generally, it is not necessary to feed down much grease on to ball bearings, especially if they remain cool.

Commutator.—It is found that a certain amount of the carbon of the brushes is worn off and adheres to the surface of the commutator. If this be allowed to remain, sparking will ensue to the detriment of the machine. This carbon is,

however, very easily removed with a clean rag. If it cannot be removed in this manner, a piece of very fine glasspaper may be used, and applied to the commutator whilst it is running,

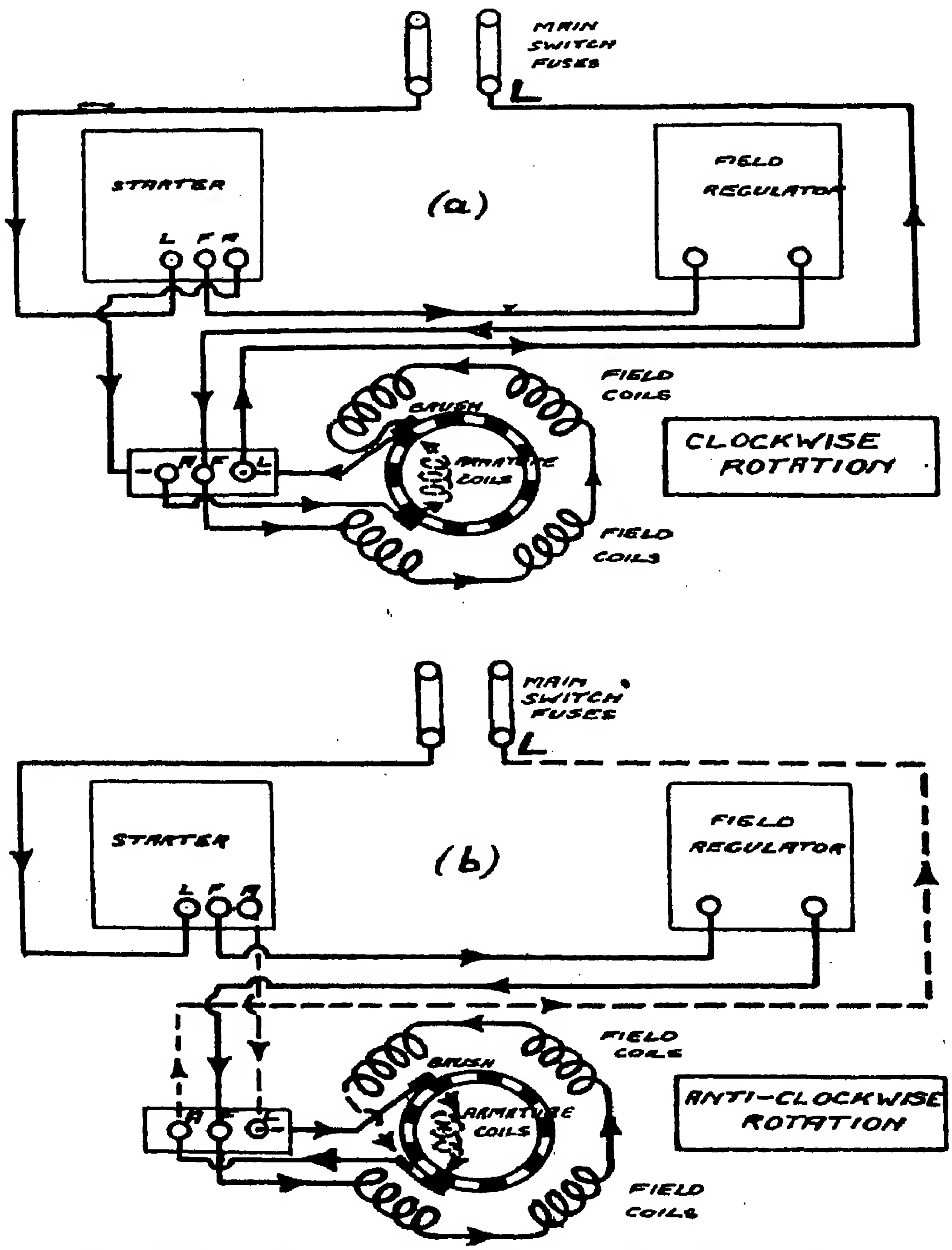


FIG. 100.—Wiring Diagrams for Changing Direction of Rotation of Armature.

by means of a wooden block so shaped as to fit on the surface of the commutator. On no account must emery cloth be used. It may be found advantageous occasionally to wipe the

commutator with a cloth smeared with just a trace of clean vaseline, afterwards removing as much of the vaseline as possible with a clean cloth.

The machine must be kept as free as possible from oil and dust. The tension on the brushes must be just sufficient to ensure good electrical contact with the commutator. In a great many cases, commutators have been grooved and scored through carelessness on the part of operators in putting too much tension on the brushes. When the machine is revolving slowly, there should be none of the shrieking sound which is so often met with. Any such noise is a clear indica-

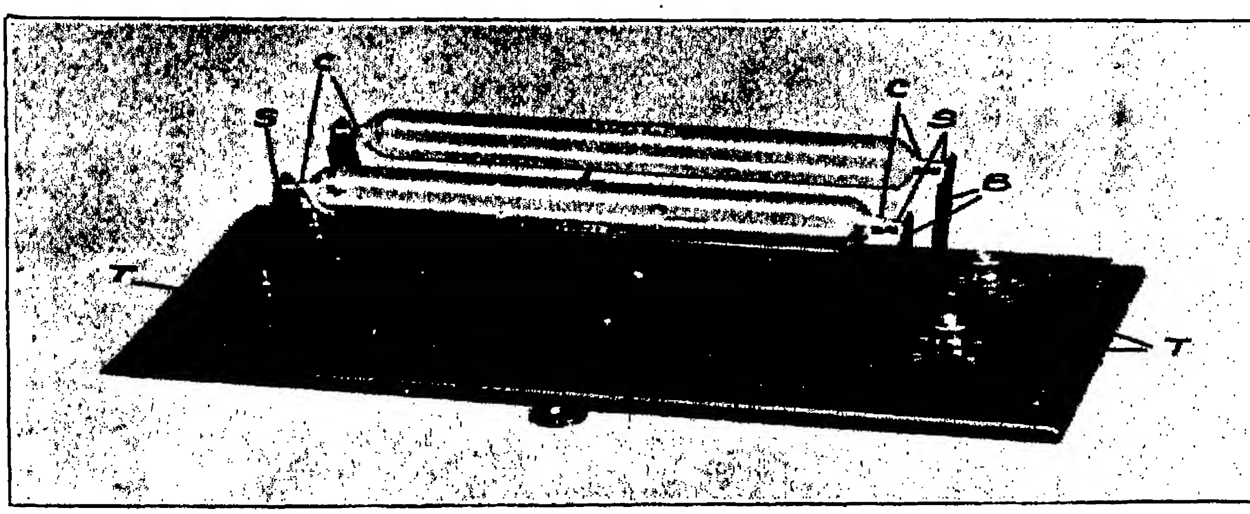


FIG. 101.—GUARD LAMP BOARD.

B, Brass Springs. C, Metal Caps on Ends of Lamps. L, Straight Filament Lamps. S, Brass Sockets on Springs. T, Terminals.

tion that the brushes are pressing too tightly on the commutator.

Brushes.—The brush-holders should be so arranged that the brushes project about a quarter of an inch before they reach the commutator. It will be found that after putting in a new brush, a certain amount of sparking may take place. This will soon rectify itself, as the surface of the brush adapts itself to the radius of the commutator. The upper end of the brush is fitted with a copper connection, and care must be taken that the brush is never so far worn that this copper comes in contact with the commutator, as this would result in great unevenness being produced.

The correct position for the brushes is that in which they are placed when a chisel mark on the end plate carrying

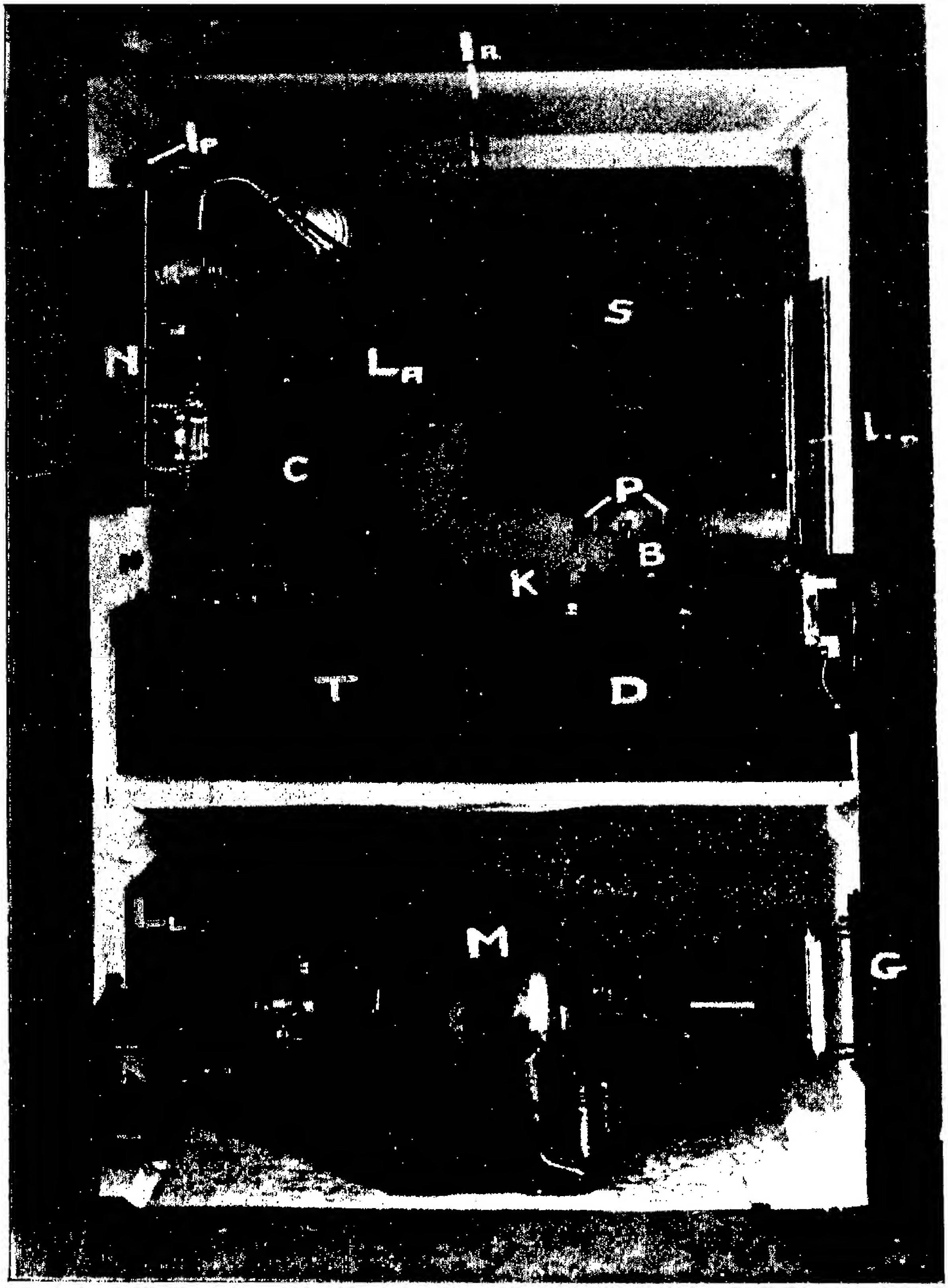


FIG. 102.—1½-K.W. PLAIN DISCHARGER TRANSMITTING SET, FITTED IN SHIP'S SILENCE CABIN.

B, Busbars.—C, Air Core Protector Chokes.—D, Plain Discharger.—G, Guard Lamp Board.—H, Main Switch.—IP, Partition Insulator.—IA, Aerial Leading-in Insulator.—K, Condenser.—LL, Low Frequency Primary Inductance.—LP, H. F. Primary Slider Inductance.—LA, Aerial Tuning Inductance.—M, Converter.—N, A. C. Switchboard. —P, Jigger Primary Terminals.—R. Field Regulator.—S, Jigger Secondary.—T, Transformer.

the brush-holders, coincides with a second chisel mark on the frame of the machine.

Guard Lamps.—A straight filament lamp is usually connected in shunt across the armature leads, and another one across the field leads of the rotary converter, as a discharge circuit to protect the respective windings from the effects of any oscillatory surges which might be induced from the high frequency circuits during wireless transmission. The two lamps are mounted between two pairs of brass springs, fixed on a baseboard supplied with terminals, as in Fig. 101. Each of the springs marked B is fitted with a terminal, T, and a small socket, S, which takes the metal cap C at the end of the lamp L.

LOW FREQUENCY PRIMARY CIRCUIT.—The second circuit to be discussed, is the low frequency alternating circuit, which includes a switchboard, regulating inductance, manipulating key, magnetic key, and the primary winding of a transformer.

The A.C. Switchboard.—This piece of apparatus consists of a slate panel mounted on a cast-iron frame, fitted with an ammeter with short-circuiting plug, a voltmeter with key, a double pole switch, fuse ways, and a pilot lamp.

The switch is of the type already described in the D.C. circuit. The connections of the switchboard are shown in Fig. 103. The feeding mains are brought from the brushes on the slip rings of the rotary-converter, to the lower extremities of the switch.

Pilot Lamp.—These ends of the switch are also permanently connected to the pilot lamp, so that when the converter is supplying alternating current to the switch-board, the lamp should glow whether the switch be closed or open. The switch contacts are connected as follows. The left-hand contact direct to the upper end of one fuse, and the right-hand contact to the upper end of another fuse, passing first through the ammeter.

Fuses.—These are of the cartridge type and capable of carrying 30 ampères. The fuse wire is contained in a fibre cylinder fitted with brass terminal lugs at either end, as in Fig. 104. The space between the wire and the case is filled with asbestos, sand, or other non-flammable material, and its use is, of course, to prevent the molten metal being scattered about in the event of the fuse blowing. The distributing

leads to the remainder of this circuit are taken from the lower ends of the two fuses.

One side of the voltmeter is connected to the bottom of

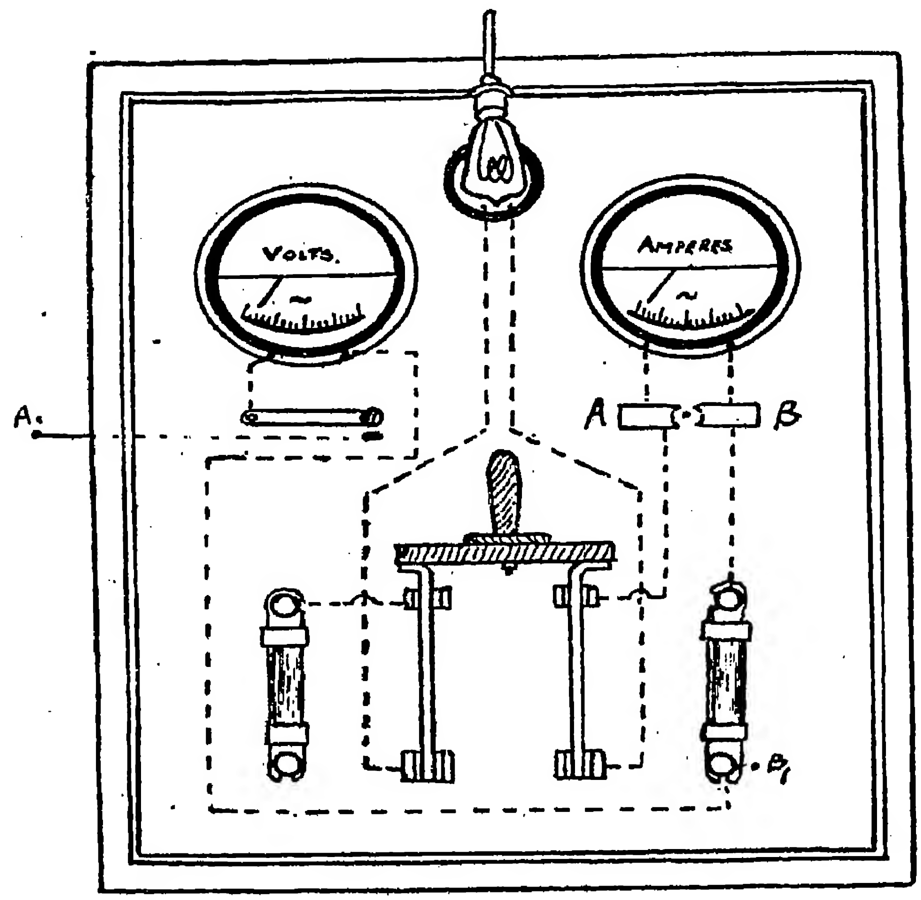


Fig. 103.—1½-K.W. A.C. Switchboard.

the right-hand fuse, and thence to one end of the transformer primary, and the other side is connected to the voltmeter key. The second terminal of the key is supplied with a lug, from

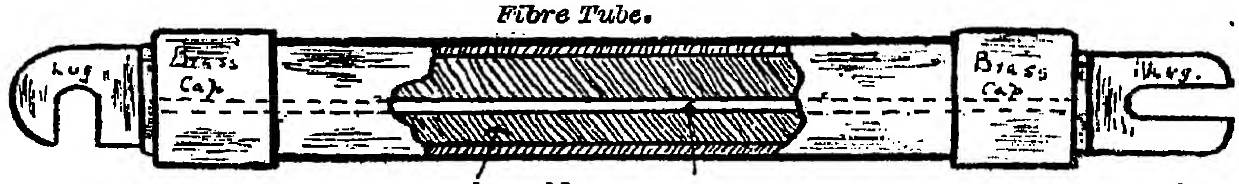


Fig. 104.—Cartridge Fuse.

which a connection is taken to the other end of the transformer primary. Fig. 105 shows how the various pieces of apparatus used in this circuit are arranged in series, and each

piece will now be discussed in proper order commencing at the left-hand fuse.

Low Frequency Iron Core Inductance.—This consists of two bobbins each wound with 360 turns of No. 12 D.C.C. (double cotton covered) copper wire, wound in three layers. An open-ended iron wire core completely fills the interior of each bobbin. The two are mounted side by side in a teak box and connected in parallel, tappings being taken from suitable points

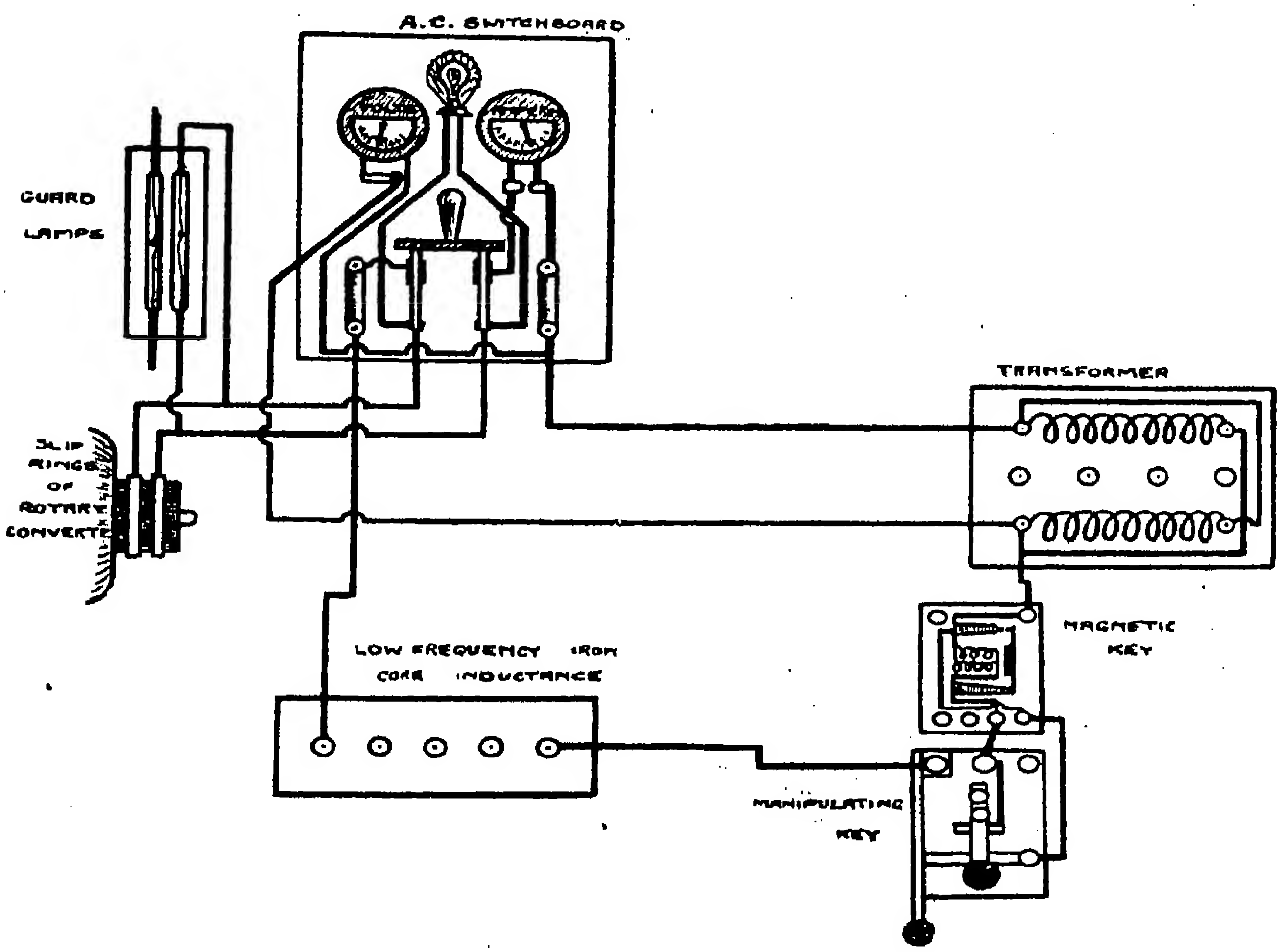


FIG. 105.—Low Frequency Primary Circuit.

to five terminals mounted along the centre of the box. The inductance obtainable has an approximate range of from ·0005 to ·01 of a henry. The figures 1, 1, $\frac{1}{2}$, $\frac{1}{2}$, are stamped between the terminals, and refer to the amount of wire between the respective terminals reckoned in layers. Fig. 106 shows diagrammatically how the connections inside are arranged, each layer being represented for the sake of clearness as a separate coil.

The formula for the natural frequency of a circuit has

already been given, and the phenomenon and effect of resonance briefly explained. If the leads from an alternating current machine, be connected to the two sides of a condenser respectively, we know that in order to bring about resonance in the circuit, the capacity and inductance must be so adjusted that the frequency of the alternating current is the same as the natural frequency given by the formula

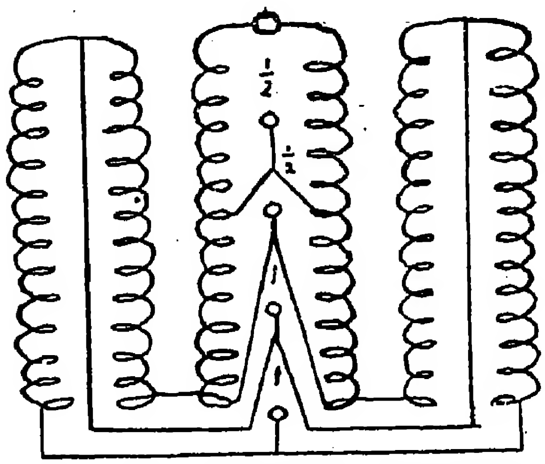


FIG. 106.—Winding of Low Frequency Iron Core Inductance.

$$n = \frac{1}{2\pi\sqrt{KL}}.$$

If, however, a transformer is inserted in the circuit, so that the inductance is connected to the primary, but the condenser is connected to the transformer secondary, then it is found that the formula for frequency must be modified to (see Figs. 108, *a*, *b*, *c*)—

$$n = \frac{1}{2\pi T\sqrt{KL}},$$

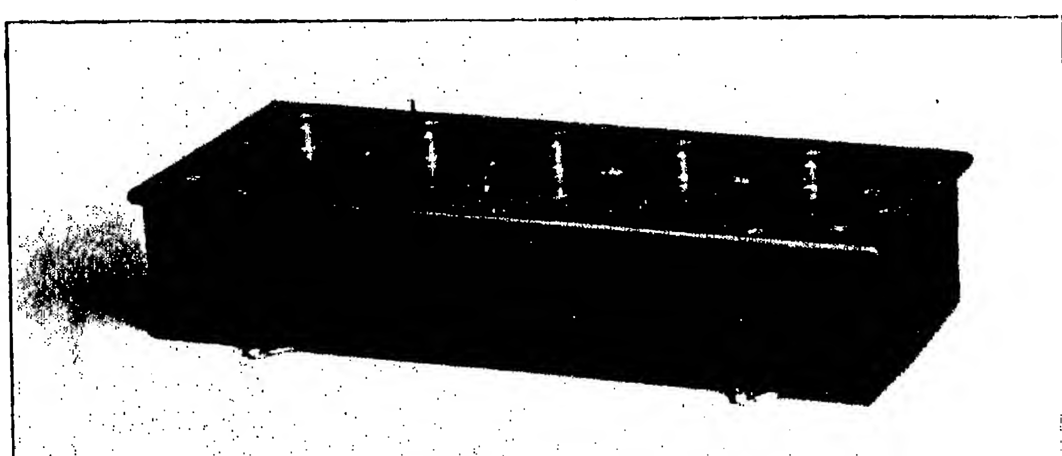


FIG. 107.—Low Frequency Iron Core Inductance.

where T is the ratio between the number of turns of wire in the secondary and the number of turns in the primary.

Now the circuit under discussion is of this type, as will be seen later.

The use of this low frequency iron core inductance is

therefore to put the circuit in resonance with the alternating current frequency, so as to most efficiently charge the condenser.

The Manipulating Key.—This part of the circuit scarcely

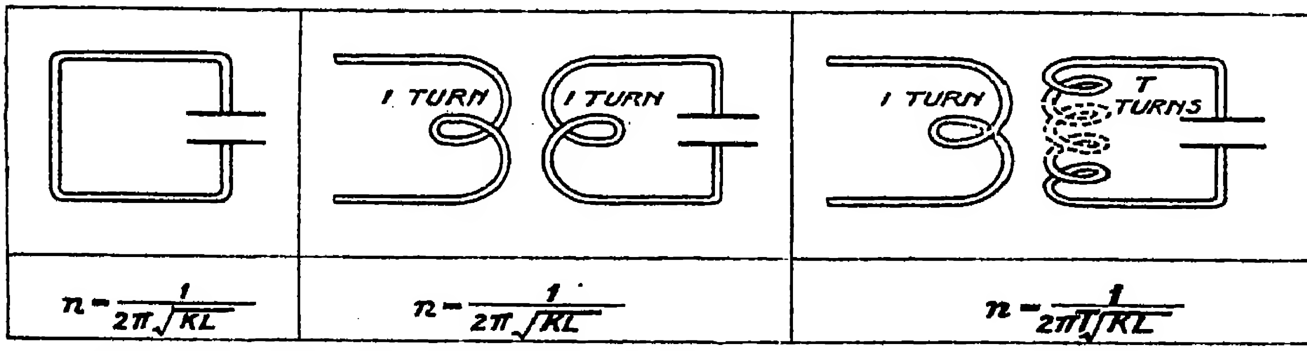


FIG. 108.—Natural Frequency of Circuit containing a Transformer.

needs explanation. It is of a similar pattern to the ordinary telegraph key, with the exception that it is somewhat heavier.

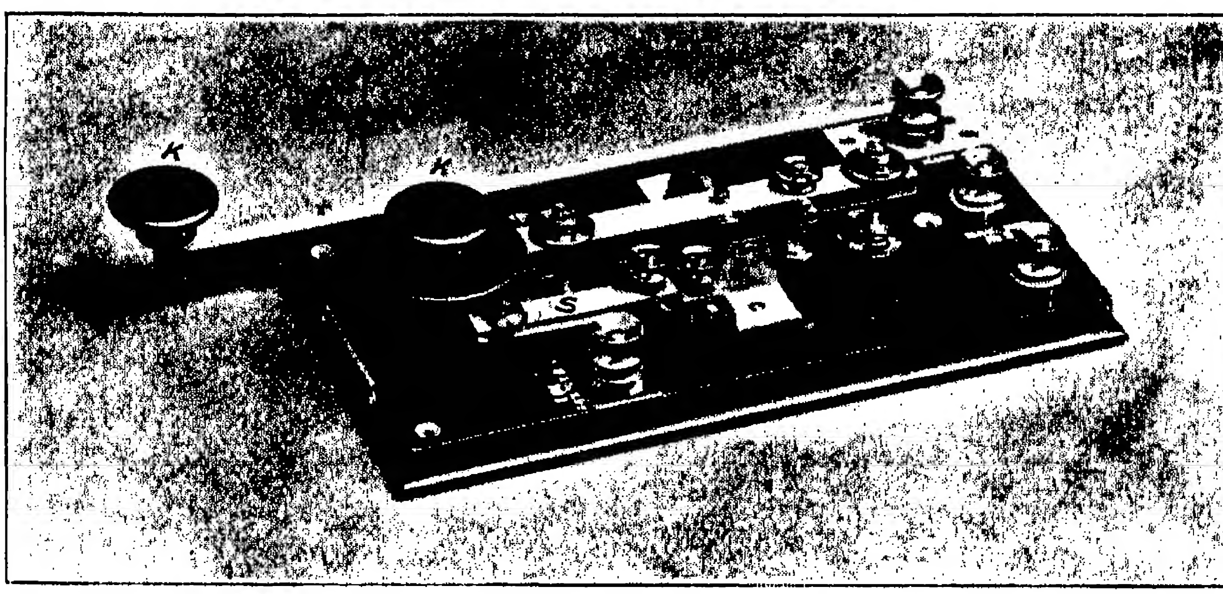


FIG. 109.—MANIPULATING KEY.

A, Contact adjusting Screw.—B, Back Stop.—C, Ebonite Cam for adjusting Short Circuit Contacts.—D, Spring adjusting Screw.—E, Back adjusting Screw.—K, Ebonite Knobs.—L, Side Lever.—S, Telephone Short Circuiting Springs.—T, Short Circuiting Terminals.

As heavy currents are to be carried, the platinum contact pieces are of rather large cross section. The insulating knob is also of a heavier type, and the operator is further

protected from shock by means of an ebonite disc between the knob and the brass bar of the key.

The play of the key may be regulated by means of the

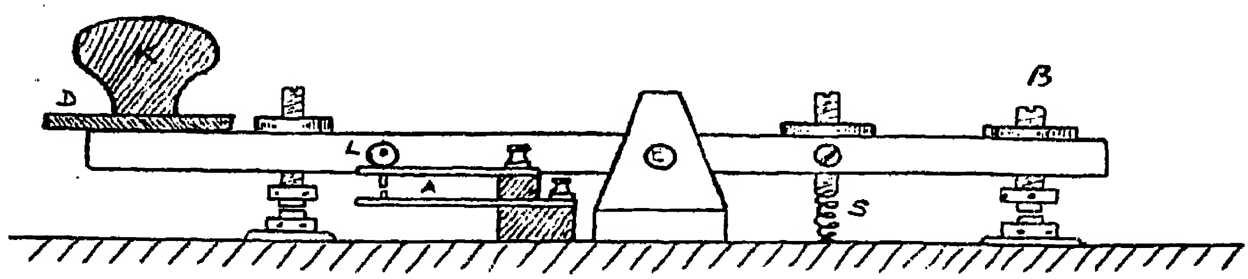


FIG. 110.—Manipulating Key.

adjustable back stop B, and the tension on the key by means of the spring S, shown in Fig. 110. D is the ebonite disc, and K the knob. A pair of small brass arms, A, fitted with contact

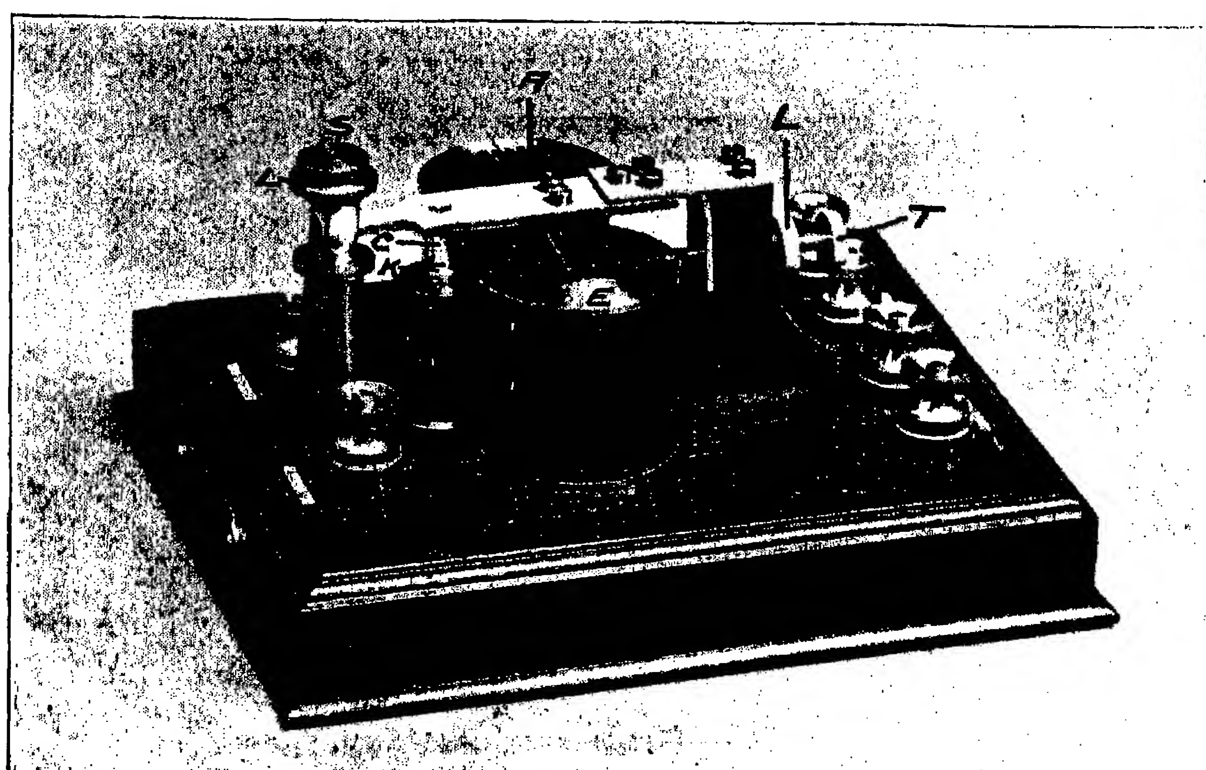


FIG. 111.—SINGLE MAGNETIC KEY.

A, Slotted Armature.—C, Armature Contact.—E, Electro-Magnet Bobbins.—K, Pillar Contact.—L, Lock Nut.—S, Adjusting Screw for Armature Play.—T, Adjusting Screw for Tension of Spring.

pieces, the break between which is regulated by means of the cam L, (consisting of a piece of ebonite tube with a hole eccentrically bored through it, and held in place by means of

a brass pin screwed into the main bar of the key,) is also supplied, the use of which will be explained later.

Fig. 112 shows a plan of the key. A side lever, S, with an ebonite handle, E, is used as an emergency switch at the hand of the operator for breaking the circuit if required. The internal connections between the working terminals are also shown. The terminal L is fitted on the end of a brass strip, B, running across the key, the other end of this strip forming a socket, in which the side lever rests. The idle terminal connects to the back contact, which on this set is used simply as a back stop. This key is used to form the dots and dashes of the Morse code by allowing the alternating current to flow only when it is depressed.

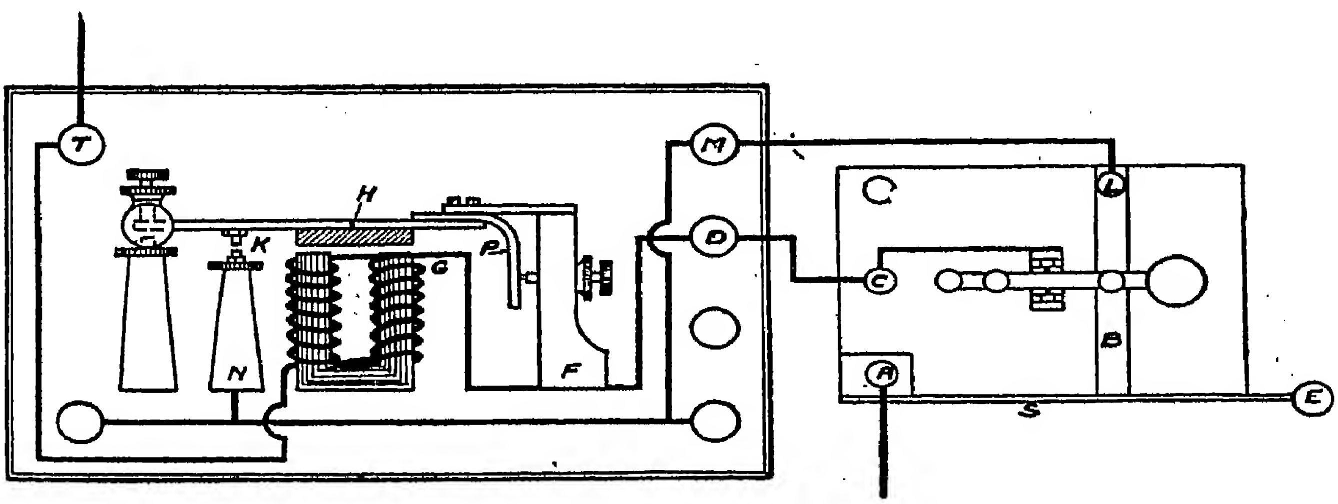


FIG. 112.—Magnetic Key Connections.

The Magnetic Key.—As already explained, the E.M.F. of an alternating current is continuously changing in direction and magnitude. If the circuit be broken at the manipulating key at a moment when this value is at a maximum, a spark is formed at the contacts, which, in addition to burning away the expensive platinum, makes the contacts dirty and prevents rapid working. In order to obviate these two evils a magnetic key is introduced. As its name implies, this key depends for its action on the principle of electro-magnetism. Two coils of No. 14 D.C.C. wire are wound on boxwood bobbins, which are mounted in parallel on two slotted soft iron cores fixed to an iron yoke in the base. A slotted armature is mounted above these coils on a brass arm, which is attached by means of a flexible spring at one end to a brass supporting pillar, and which carries on the under side of the other end a platinum

contact. Immediately under this contact is a second one, which is fixed at the top of another supporting pillar. A third pillar carries a screw adjustment, by means of which the play between the two contacts may be adjusted. The connections between the various parts of this key are shown in Fig. 112. In order to better explain its action the manipulating key is also shown connected up.

Action of Magnetic Key.—Before depressing the manipulat-

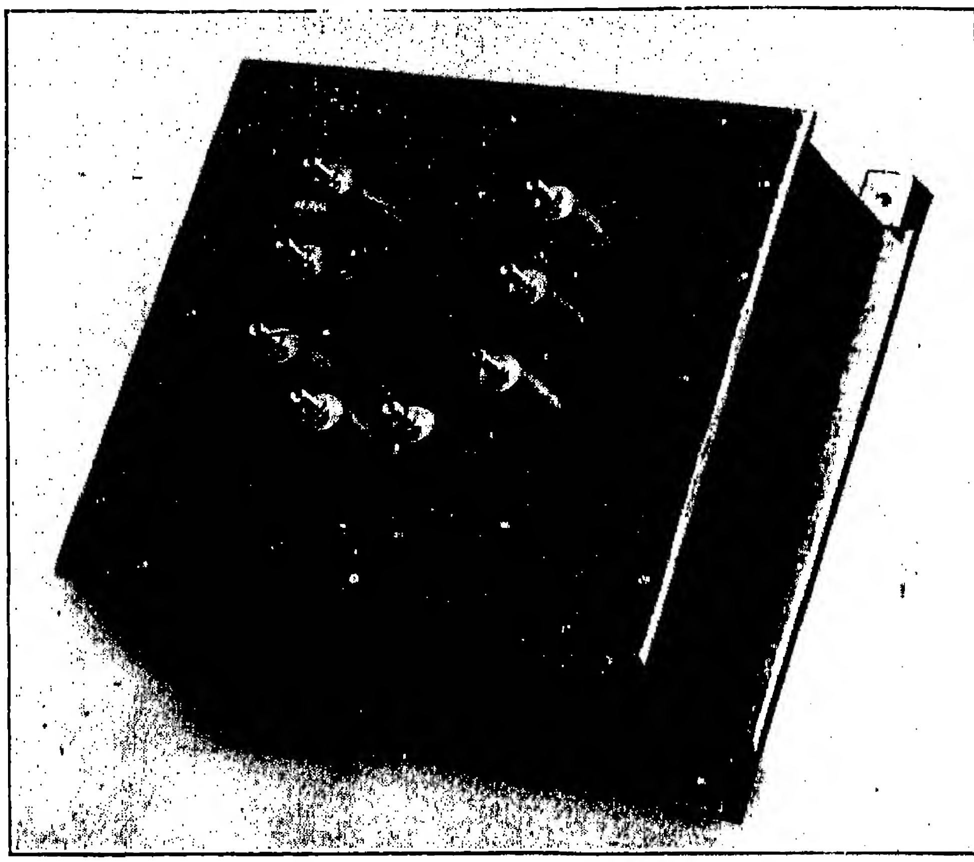


FIG. 113.—AERIAL TUNING INDUCTANCE (TRANSMITTING).

E, Ebonite Bushes.—S, Brass Plug Sockets.

ing key the circuit is open. On depressing it, however, any current entering at A passes along the side lever to the brass strip B, through the front contacts and along the bar of the key to the terminal C, which is connected to the terminal D of the magnetic key. D is internally connected to the base of the pillar F, and also to the junction between the two coils at G. The other ends of the coils are connected to the terminal T. As the current passes through the coils, the cores are powerfully magnetised and the armature H is attracted, contact being

made at the point K. Returning to the manipulating key, it is now seen that a second path has been provided for the current. It may pass completely along the brass strip B, and leaving the manipulating key at the terminal L enter the magnetic key at M, and after passing through the internal connection to the base of the pillar N, it may continue up this pillar, through the contacts and along the armature support, ultimately rejoining the original circuit at the base of the pillar F. Thus, if the manipulating key be released there is still a path along which the current may pass. But the current used in this circuit comes to a zero value 100 to 120 times per second, so that a point of zero value will follow immediately after the manipulating key has been released. When the current is zero, its power to magnetise the cores of the coils is

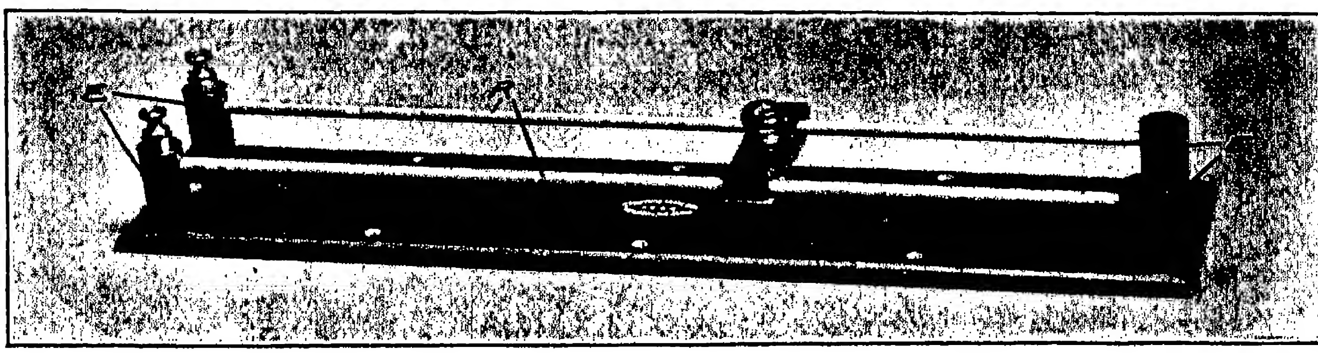


FIG. 114.—SLIDING INDUCTANCE.

B, Brass Slider.—E, Ebonite Pillars.—R, Brass Rods.

gone, and the armature flies back to its original position under the influence of the spring P, thus breaking the second circuit. As another path remains for the current to follow at the breaking of the manipulating key contacts, very little sparking occurs between them, and as the current is at, or near, zero value when this second path is broken, very little sparking occurs at the magnetic key contacts, so that all chance of dirty or burnt contacts is obviated, and the operator is enabled to operate as fast as the hand can work.

The cores of the coils and the armature are slotted to reduce eddy currents, and so to keep down the heating of the iron.

A simple theoretical diagram illustrating the working of the magnetic key is shown in Fig. 115.

Adjustment of Magnetic Key.—The following is a good

method of adjusting the magnetic key. All tension should be removed from the armature control spring, and a piece of paper inserted between the magnet cores and the armature. The pillar contact should then be screwed up, until it is just touching the contact carried on the under side of the armature support, and should be locked in this position by means of the lock-nut. Tension should then be put on the armature control spring until a space of about 1/16 of an inch separates the pillar and armature contacts.

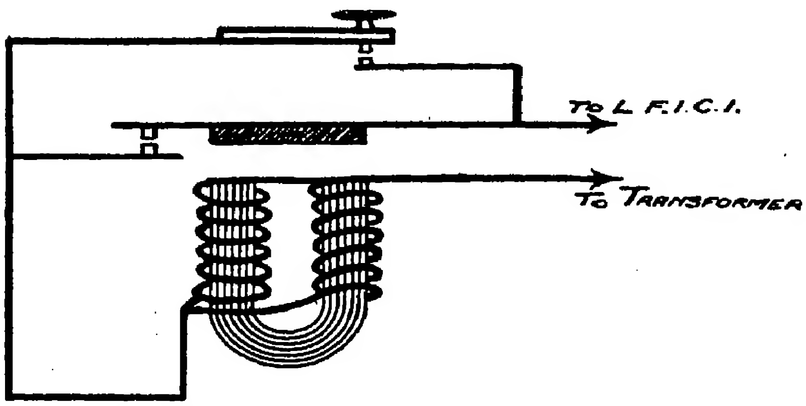


FIG. 115.—Theoretical Sketch of Magnetic Key.

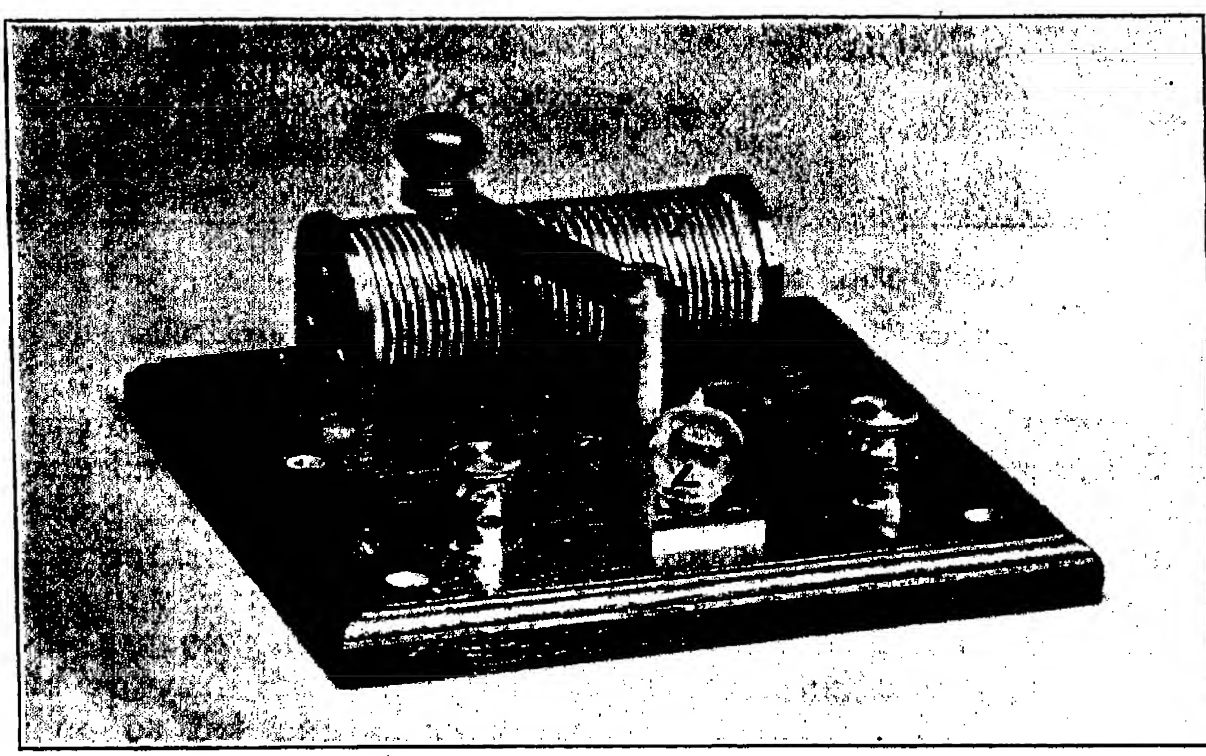


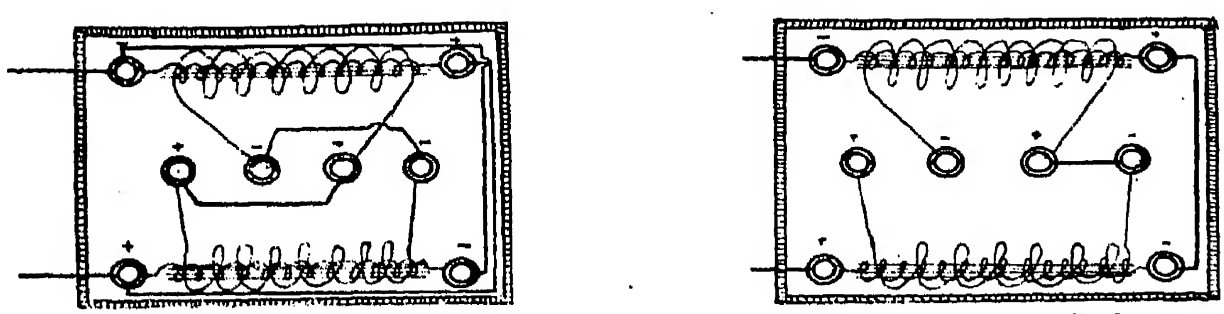
FIG. 116.—TUNING LAMP.

A, Brass Contact Arm.—I, Copper Inductance Coil.—K, Ebonite Knob.—L, 4-Volt Lamp.

The top stop may then be fixed so that it just touches the upper side of the armature support.

The final adjustments must be made while the current is passing, and it will be found that delicate adjustments of the control spring and the top stop are required, to eliminate successfully sparking between the contacts.

The Transformer.—This piece of apparatus consists of two transformer coils contained in a lead-lined teak box. Each coil consists of a primary winding of comparatively thick copper wire wound over a core of stranded soft iron wire, and a secondary of fine wire consisting of a great number of turns. The ends of the windings are connected to ebonite bushed terminals on the lid of the container. These terminals are marked with positive and negative signs for the convenience of knowing which are the corresponding primary and secondary of each half of the transformer. The primary terminals are arranged at the four corners of the lid, and the secondary



Primaries in Parallel.
Secondaries in Parallel.

Primaries in Series.
Secondaries in Series.

FIG. 117.—$1\frac{1}{2}$ K.W. Transformer Connections.

terminals are arranged down the centre, as shown in Fig. 117. The position of the coils in the container is also shown. It will be seen that the primary and secondary windings may be arranged in series or parallel as desired. The primaries are almost invariably connected in parallel, but as both parallel and series arrangements of the secondaries are used, diagrams are given showing the necessary connections (Figs. 117 *a* and *b*). When the coils leave the works they are covered with paraffin wax. On being placed in position, the teak container is filled with high flash insulating oil, which eventually dissolves the wax and leaves the coils in a highly insulated condition.

With the primaries in parallel and the secondaries in series, the ratio between the primary voltage and the secondary voltage is approximately 1 : 300.

In Fig. 105 the voltmeter is shown connected across the primary winding of the transformer. The ammeter is, of

course, in series with the circuit, and the readings of the two instruments give us an idea of the amount of power being used in the transformer primary. On a 110-volt D.C. circuit, the readings should be about,—

Ammeter	..	..	25 amps.
Voltmeter	..	..	75 volts.

(See paragraph on Tuning of Low Frequency Primary Circuit, page 229.)

It has been stated that the power is obtained by multiplying the volts by the ampères, and in this case the result is 1·875 k.w. It must be remembered, however, that we are dealing with alternating current, and that although the potential across the total circuit, when the circuit is in resonance, will reach its maximum value at the same time that the current reaches its maximum value, this is not the case if the potential is measured only across part of the circuit, either across the inductance alone or across the condenser alone. The difference in time between the two maximum values is reckoned in angular degrees either as a lag or as a lead. If the potential is measured only across the inductance the current will be found to lag, if it is measured only across the condenser the current will be found to lead.

In the circuit under consideration the condenser is connected through a transformer. If the transformer had no magnetic leakage there would be no current lag due to inductance, but a voltmeter connected across the primary together with an ammeter in circuit would indicate a strong current lead due to the capacity of the condenser connected to the secondary. In practice the current lead is only lessened to a small extent by the inductance of the transformer. Then to calculate the actual power in an alternating current circuit, the equation becomes

$$\text{Power in watts} = \text{Virtual ampères} \times \text{Virtual volts} \times \text{Cosine of angle of lag or lead.}$$

The cosine of the angle being always less than unity, the total number of watts is always less than the result obtained by simply multiplying the ampères by the volts taken from the instrument readings. At first sight, operators are apt to ask why they can get 1·875 k.w. out of a 1·5 k.w. set, and the above, of course, explains where the mistake is made.

HIGH TENSION CIRCUIT.—The next circuit to be considered is called the high tension or high voltage circuit, the main parts of which are the transformer secondary windings, two air-core choke coils, and the main condenser. The first require very little explanation, as the connections have already been given under the heading of "Transformer" in the explanation of the last-mentioned circuit.

The Choke Coils (Air Core).—The function of the choke coils is, to prevent the high frequency condenser discharge current from surging back into the low frequency circuit,

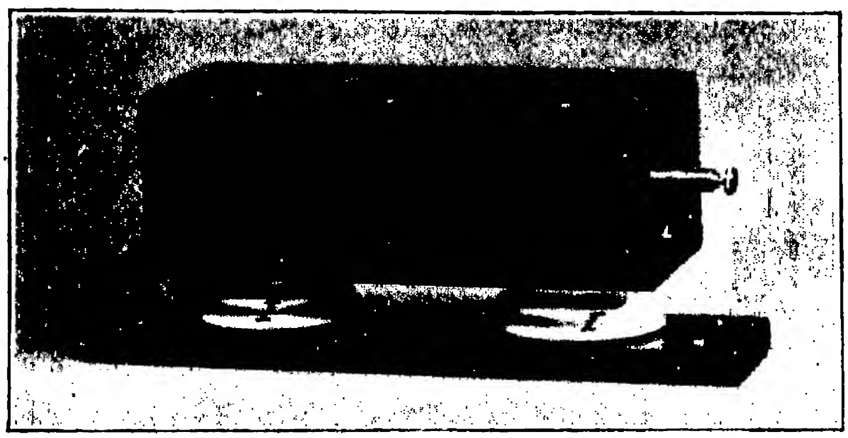


FIG. 118.—AIR CORE CHOKE COIL.

I, Porcelain Insulators.

—which might result in insulation troubles,—without interfering in any way with the low frequency condenser charging current. Each coil is wound with fine wire in a single layer on an insulated stand contained in a teak box. They each have a resistance of about 15 ohms. The total impedance in a circuit containing inductance and capacity, is given by the formula—

$$\text{Impedance equals } \sqrt{R^2 + \left(2\pi nL - \frac{1}{2\pi nK}\right)^2}$$

where R represents resistance, n the frequency, L the inductance, and K the capacity. From this it is seen that if n be increased the impedance increases.

In the case of the coils under discussion the value of n for the charging current is so low that the current has no difficulty in passing through them. But in the next circuit to be considered, oscillating currents having an exceedingly

high value of n are circulating. The main condenser is common to the two circuits, but the chokes prevent the oscillating currents from passing back to the transformer windings, because of the high value of their impedance for the extremely large value of n.

Again, the value of R is very much greater for a high frequency current than for a direct or low frequency current. It is found that currents of high frequency are confined to the surface of a conductor, and do not distribute themselves uniformly through it, and if the current is unevenly distributed the resistance of the conductor becomes much greater.

It will be seen, therefore, that the value of R in the calculation for impedance, also tends to increase the total value of the latter for high frequency oscillations, and makes the choking effect more pronounced.

It may be mentioned further, that the conductors in the oscillatory circuits, consisting either of copper strip, copper tube, or cable containing a great number of strands, are invariably made of large surface, in order to make the skin resistance as low as possible.

Connection of Choke Coils to H.F. Primary Circuit.—The choke coils, because they convey the charging current, are often connected to the oscillating circuit at the condenser (see Fig. 123). It is also frequently convenient to connect them here, and it may be misleading to show them connected otherwise in a diagram without giving further explanation. But this is the best position to make them resonate should the wave in the condenser circuit approach that of their period, which is to be avoided. They are always designed to have a much greater period than the maximum of the condenser circuit, but it is an added safeguard to connect them at the discharger instead of the condenser, as resonance effects in them are then minimised.

The Main Condenser.—This piece of apparatus is used to store up energy for the production of oscillating currents in a closed oscillatory circuit.

As this condenser has to withstand very high voltages, the dielectric consists of the best flint glass. The condenser consists of a lead-lined teak container, in which two separate banks of sheet zinc and glass are placed, each bank being carried in a zinc cradle to facilitate its removal for purposes of repair or adjustment. In each bank there are 35 sheets of zinc shaped as in Fig. 119, and 36 sheets of glass. The zincs

are alternately arranged with the lugs as shown, a sheet of glass being placed between every two adjacent zincs. It is thus seen that 17 zincs have one lug near the right-hand edge of the glass plates, and 18 zincs have one lug near the left-hand edge of the glass. The 17 plates are connected by means of brass bolts supplied with washers, to keep the lugs in a rigid upright position. The height of the brass bolts above the top edge of the glass plates is fixed by means of small leather stools. The 18 plates are similarly connected together. Only 34 of the 36 glass plates are active, the remaining two being guard plates. Each set of zincs has two brass bolts, one

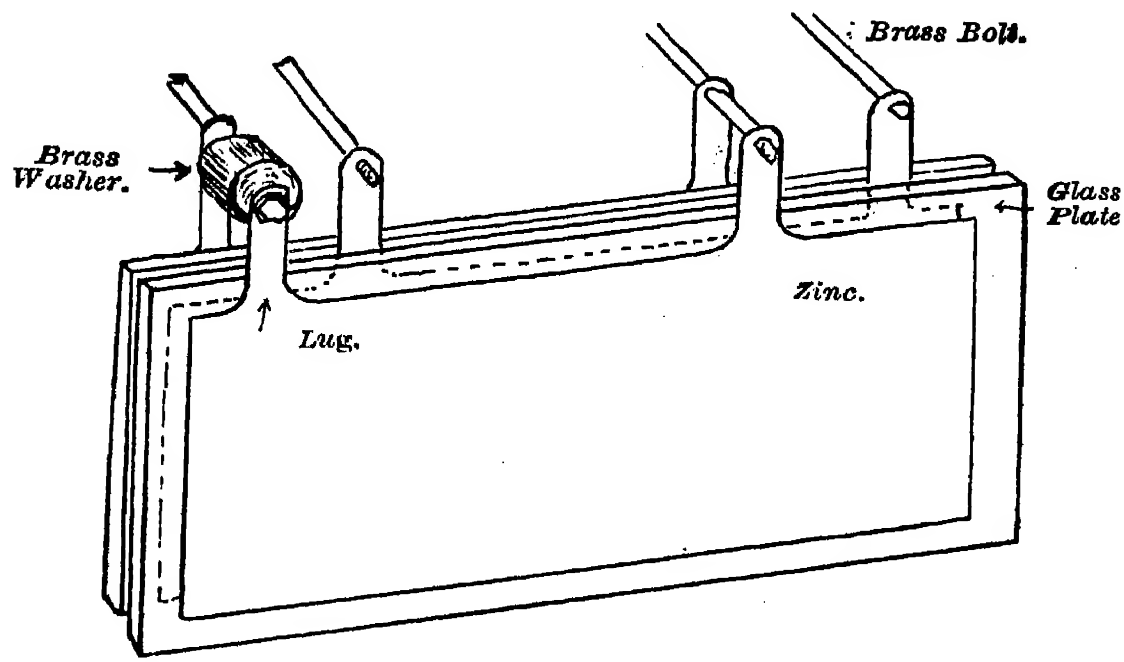


FIG. 119.—Arrangement of Plates in Main Condenser.

through each set of lugs, thus ensuring a perfectly rigid disposition between the glass plates. Each bank is similarly built up and stands in its cradle on a cork pad, being packed on the sides with paraffined, or oiled, white wood. Small U-shaped copper strips are used to connect the bolts of the two sets of 18 zincs, the two cradles being so placed in the container that the 18 zincs of each are in line.

The lid of the container is fitted with four brass terminals, each passing through heavy ebonite bushing. One of these terminals is marked with a cypher and has no internal connection. Two terminals marked "seventeen" are each connected to the middle of one of the bolts connecting each set of seventeen zincs. The fourth terminal marked 36 is

connected to the middle of one of the bolts connecting one set of 18 plates.

The two parts of the condenser may be very quickly placed either in parallel or series by means of two brass connecting strips, each being drilled at one end and slotted at the other. When the two strips are parallel to each other, as in Fig. 121 (*a*),

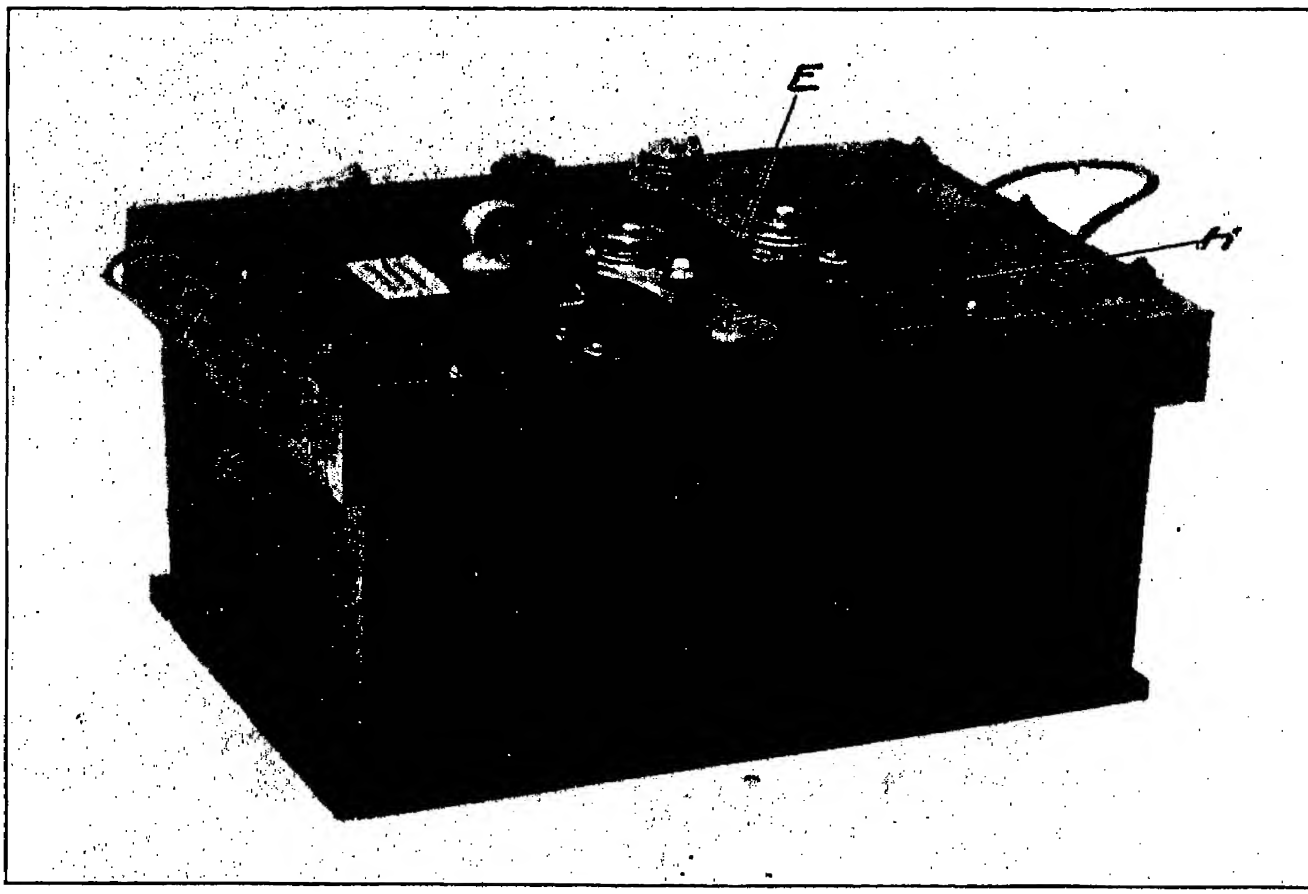


FIG. 120.—HALF-PLATE CONDENSER (CLOSED) WITH HANDLE CHANGE-OVER STRAPS.

E, Ebonite Bridge Piece.—H, Handle Change-Over Straps.—K, Condenser Container.

the two halves of the condenser are in parallel, as is seen from the conventional drawing of the condensers. When they are in a diagonal position, as in Fig. 121 (*b*), the two halves are connected in series. Since each half is exactly similar to the other, the capacity of the parallel arrangement is four times that of the series arrangement, because for parallel capacities,—

$$K = K_1 + K_1 = 2K_1$$

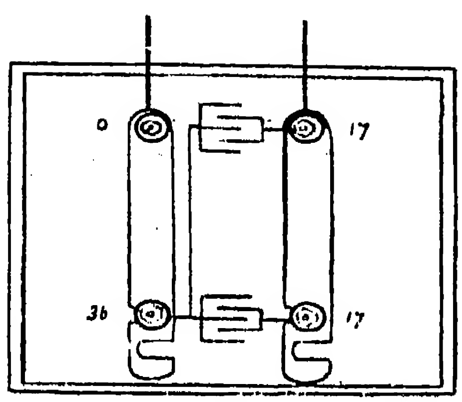
and for series capacities,—

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_1}=\frac{2}{K_1} \text{ or } K=\frac{K_1}{2}$$

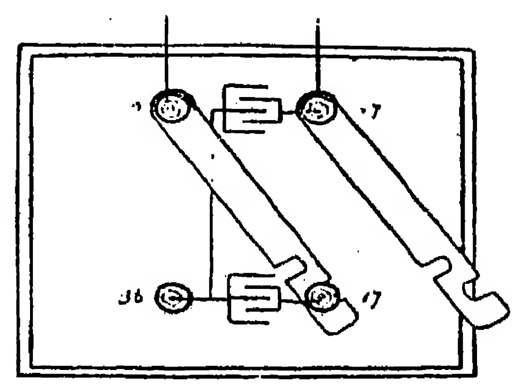
The capacity of each half is about ·0325 microfarad, so that the capacity of the series arrangement is ·0162 microfarad and that of the parallel arrangement is ·065 microfarad.

The glass plates are $\frac{1}{10}$th of an inch thick, and each plate is separately tested to stand a maximum voltage of at least 27,000 volts. The main terminals are the ones marked 0 and 17 on the same bank.

If the condenser in a closed oscillating circuit consists, say, of a Leyden jar, it is often found that a brush discharge



(a)
Parallel.



(b)
Series.

FIG. 121.—Main Condenser Connections.

takes place at the edges of the inner and outer coatings of foil. The brush discharge consists of a great number of fine twig-like ramifications, which are seen to start from the foil edges, and spread out towards the edge of the dielectric. These discharges are accompanied by a sharp hissing or crackling sound, and, of course, a great deal of the energy of the condenser is lost. To reduce the loss as much as possible, the glass is usually coated with some non-hygroscopic insulating material, such as shellac varnish.

In the case of the main condenser just described, brush discharging is to a great extent prevented by immersing the condenser banks in high flash insulating oil.

THE HIGH FREQUENCY PRIMARY OR CLOSED OSCILLATING CIRCUIT.—The main condenser forms part of this circuit, and is connected in series with a discharger, a variable inductance,

and the primary of an oscillation transformer, which last is more usually called a jigger, as it is used for the transformation of trains of oscillations or "jigs," as they have been styled, from one circuit to another. One side of the main condenser is connected to one terminal of the discharger.

The Plain Discharger.—The spark discharges between two mushroom-shaped cast-iron electrodes, which are mounted on

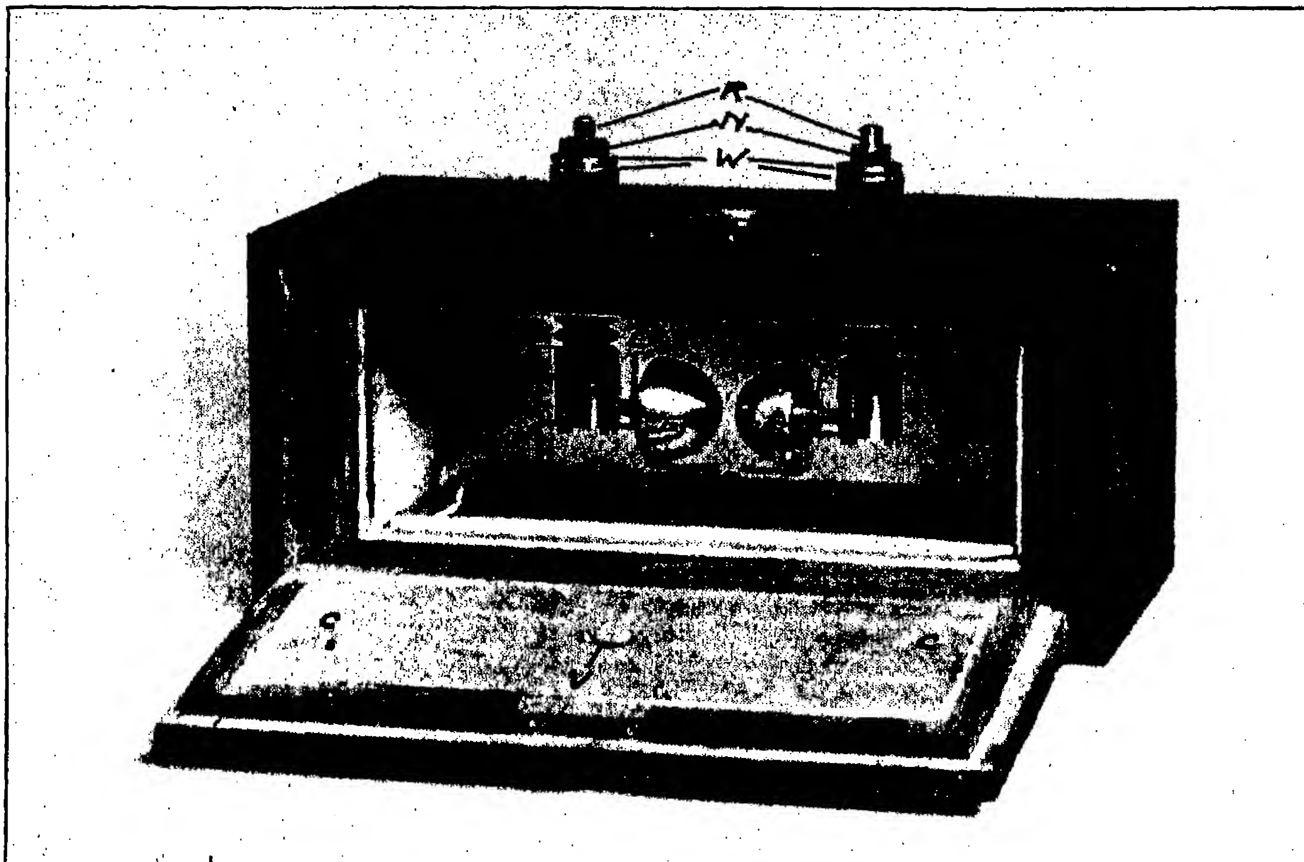


FIG. 122.—DISCHARGER (FIXED TYPE).

B, Teak Box.—C, Lead Lining backed with Asbestos.—E, Cast-Iron Electrodes.—L, Lock Nuts.—N, Lock Nuts.—P, Protective Spark Points.—R, Brass Rod.—S, Ebonite Pillars.—T, Zinc Tray.—V, Chamois Leather-covered Vent Holes.—W, Brass Washers.

two horizontal brass spindles supported on vertical brass rods. These brass rods pass through heavy ebonite pillars, which are brought to the outside of a teak container, and are supplied on their upper extremities with suitable washers and nuts for making the required external connections. The container is made of 1½-inch teak, and is lined first with asbestos and afterwards with lead in order to deaden the sound of the discharge. A zinc tray is placed in the bottom of the container, in which

quicklime is placed to absorb the moisture and the gases produced when the spark is taking place. The cast-iron electrodes are screwed on to the horizontal spindles, the thread on which is of such a pitch that one half turn gives an adjustment of one millimetre. Lock nuts are provided, so that when the electrodes have been set up to a proper distance apart they can be permanently fixed in position. Two sliding brass strips are mounted immediately under the electrodes, and are set at such a distance apart that all danger of the condenser breaking down through excessive voltage is avoided. Fig. 123 shows this discharger and does not require any further explanation. The

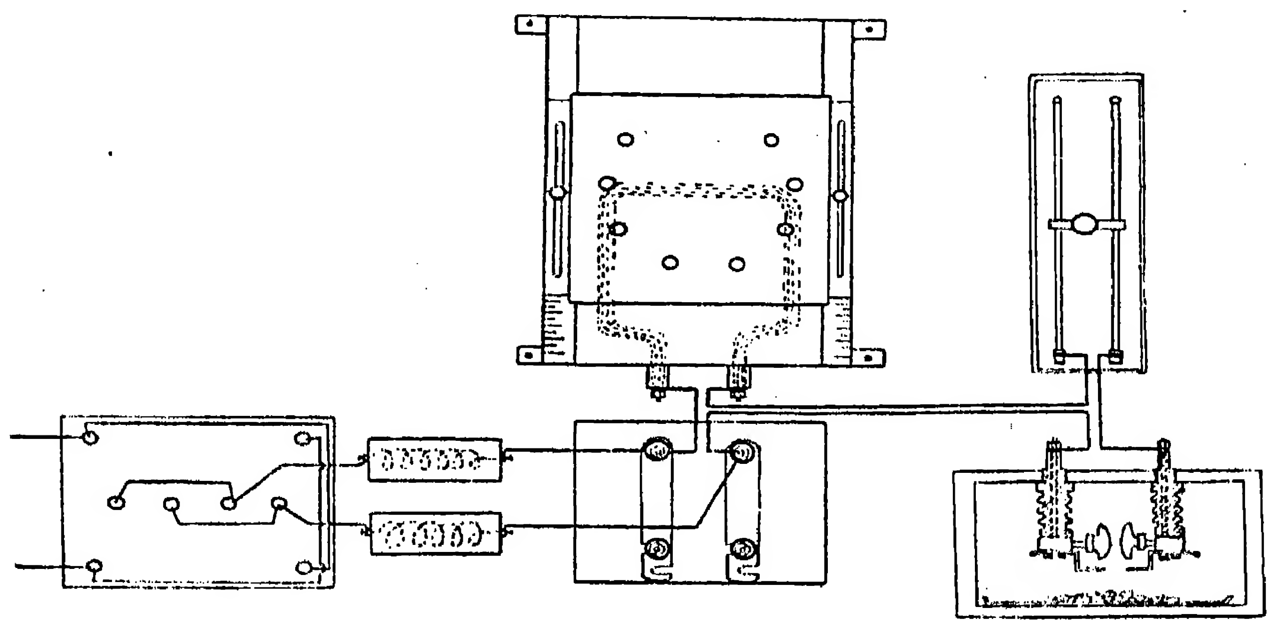


FIG. 123.—High Tension and Closed Oscillatory Circuits.

second terminal of the discharger is connected to one side of the high-frequency sliding inductance.

The High-frequency Sliding Inductance.—This consists of two brass rods of round section, mounted on four ebonite pillars on a wooden base, bridged by a sliding brass clamp by means of which the inductance may be varied. The inductance is a minimum when the bridge is at the terminal end, and its maximum value is ·51 microhenry. The condenser, it will be remembered, is only capable of adjustment for two capacities, or, admitting the possibility of using one bank separately, for three. This sliding inductance is therefore necessary for obtaining a final slight adjustment for the production of oscillations of the required frequency. This instrument is shown in Fig. 123.

The Jigger.—This instrument consists of a primary winding of one turn, and a secondary of eight turns. The primary winding is built up of 63 strands of No. 20 copper wire, each

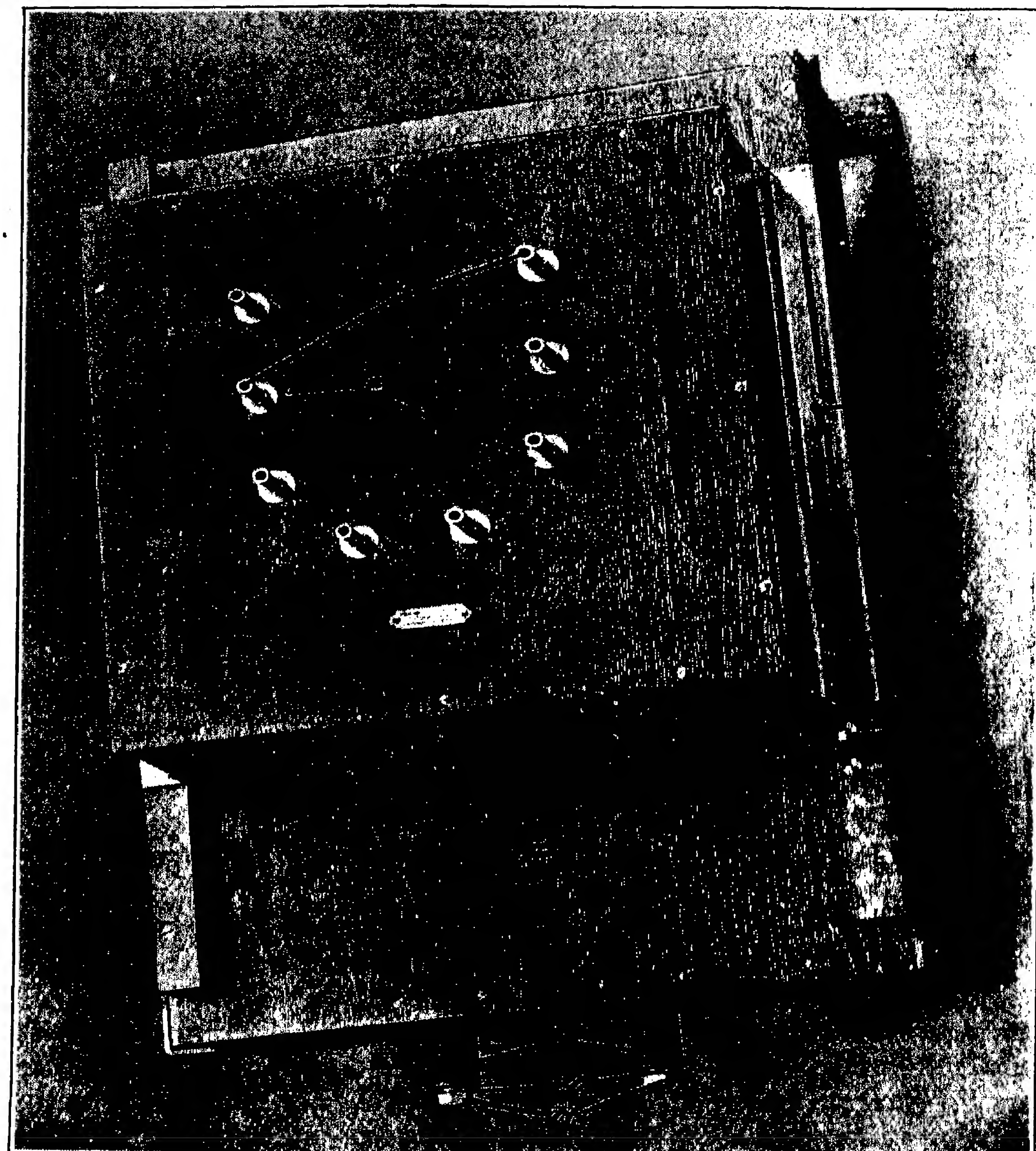


Fig. 124.—Transmitting Jigger (North Foreland Type).

B, Brass Slider.—E, Ebonite Bush.—L, Coupling Calibration.—M, Jigger Secondary Casing.—N, Terminal Nuts.—P, Jigger Primary Casing.—S, Brass Plug Sockets.—T, Brass Thumb Screws.—W, Brass Washers.

strand being cotton-insulated, and the whole impregnated with paraffin wax and shellaced. It is wound round a wooden former, square in shape, and the two ends are brought through heavy ebonite bushes through the bottom of the teak box in which it is contained, and are soldered into terminal sockets. One end is connected to the high-frequency sliding inductance, and the other end is connected to the main condenser, thus completing the closed oscillating circuit. Two standard wave lengths are used on board ship—namely, 300 and 600 metres, or approximately 1,000 and 2,000 feet. The adjustment of the closed oscillating circuit for the production of the longer wave is shown in Fig. 123. The banks of the main condenser are placed in parallel, and the spark-gap is adjusted to approximately 4 millimetres. The bridge of the sliding inductance is placed in a certain position indicated on a drawing which is left on the station by the erecting engineer. The secondary windings of the transformer are connected in parallel.

SHORT WAVE ADJUSTMENTS.—For the production of the shorter wave the main condenser banks are connected in series, the spark gap is increased to approximately 8 millimetres, the sliding inductance is altered in accordance with the engineer's diagram, and the secondary windings of the transformer are connected in series. The reason for this last change is as follows.

The energy of a charged condenser is obtained from the formula—

$$E=\frac{KV^2}{2}$$

where E is the energy, K the capacity, and V the voltage to which the condenser is charged.

Let us consider this equation in connection with the two arrangements for the short wave and long wave respectively.

Let E and E_1 represent the respective energies.

„ K „ K_1 „ „ „ capacities.

„ V „ V_1 „ „ „ voltages.

Then
$$E=\frac{KV^2}{2}$$

and
$$E_1=\frac{K_1V_1{}^2}{2}$$

In order, then, that the energy in the condenser may be the same in each case

$$E = E_1, \text{ or } \frac{KV^2}{2} = \frac{K_1 V_1^2}{2}$$

It has already been shown that $K_1 = 4K$.
Substituting in the above equation, therefore,

$$\frac{KV^2}{2} = \frac{4KV_1^2}{2}$$

multiplying each side by $\frac{2}{K}$ we get

$$V^2 = 4V_1^2$$

and taking the square root of each side

$$V = 2V_1$$

Hence we see that the voltage for the short wave arrangement must be twice that for the long wave arrangement in order to obtain the same energy. This increase in voltage is obtained by placing the secondary windings of the transformer in series instead of parallel. In consequence of the increased voltage, the spark gap must be increased in order to avoid arcing.

The connections between the various pieces of apparatus in the closed oscillating circuit, are made by means of standardised pieces of copper strip. In order to keep the inductance as low as possible these strips are placed very close together, any sparking between them being prevented by means of ebonite separators held in position by ebonite clamps. The disposition of the connections is shown in Fig. 125 (*a*), and of connections, separators, and clamps, in Fig. 125 (*b*).

THE 1½ K.W. DISC DISCHARGER SET.—The original installations on many ships, have, from time to time, been brought up to date, by modifications effected as far as possible on the apparatus already installed. The principal improvement has been the substitution of a "rotary" or "disc" discharger, in place of the "plain" discharger.

The plain discharger has two fixed electrodes, so has the rotary, but in the rotary they are far apart. A disc with a metal rim and projecting metal studs revolves between them,

and it is only during those short intervals when the studs approach very near the electrodes that a spark can occur. A spark which takes place at definite intervals, having a frequency within the range 30–20,000 per second will give an audible note. And if the spark gives a note, it can be picked out by the receiving operator from among other sparks which do not give notes, or which give notes of some other frequency. Also it follows that such signals stand a greater chance of being read through atmospherics, as all natural discharges are irregular in character.

The best note as regards quality is obtained when the

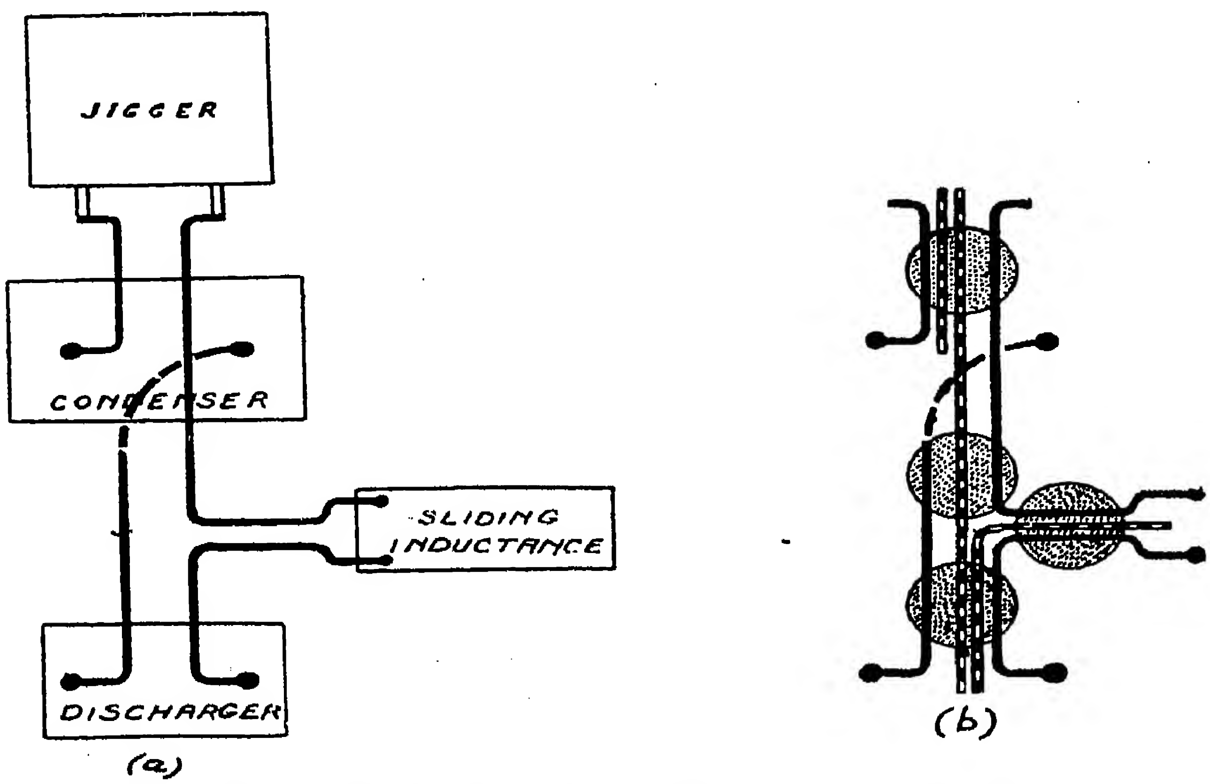


FIG. 125.—Closed Oscillating Circuit Connections, with Separators.

number of sparks per second is twice the value of the alternator frequency, and when they are completely synchronous with the changes in the alternator voltage. This means that one spark must occur at every half alternator-cycle, and always at the same relative position in the half-cycle. Now all the original 1½ k.w. machines had a frequency of 50–60 cycles. A synchronous spark every half-cycle would therefore give a note frequency of only 100–120 per second. This is very low, and although better than no note at all, it is not of much use in reading through long atmospheric discharges as it cannot be distinguished sufficiently well from them.

For this reason, when rotary dischargers were installed on the ships, it was considered advisable to sacrifice to a certain degree the quality of the note in order to obtain a gain in audibility. The sparking disc was made synchronous as regards speed by fitting it on an extension of the converter shaft, but instead of the disc having 4 equally spaced studs—the same as the number of field poles, which would ensure one spark every half-cycle,—it was given 24 studs, which cause six sparks to occur every half-cycle.

The predominant tone in the note has a frequency according to the speed of from 600 to 720 per second, and there are lower tones of less intensity mixed with it. The operator receiving from a spark of this nature finds no difficulty in reading signals through long atmospherics.

There is another advantage which follows from the use of an asynchronous 24 stud disc instead of a synchronous four stud. As it gives more discharges per second, the mean spark potential will be less, and of course the mean H.F. current will be more—the condenser energy being the same in both cases. The aerial potential and current will be affected in a corresponding degree. The current can always be easily handled, but any arrangement which tends to reduce the potential on the aerial is very welcome, as the loss due to brushing is thereby reduced, and the risk of surface insulation breakdown on all parts of the circuit,—leading-in insulator and aerial strain insulators especially,—is also reduced. But a more substantial reduction in aerial potential followed as a result of lowering the transformer ratio, which was also found necessary as explained below.

It has been already shown that best results are obtained with "plain" spark discharge, when the natural frequency of the charging circuit—consisting of alternator, low frequency tuning inductance, transformer, and condenser—agrees with that of the charging current supplied by the alternator. The same thing is true for a synchronous disc spark discharge every half-cycle. But now we must look at this tuning from a different standpoint. With a mechanically controlled spark discharge we have three frequencies to consider: (1) that of the charging current from the alternator; (2) the natural oscillation of the charging circuit; and (3) the mechanical frequency of the spark discharge. And the controlling frequency is that of the spark discharge. When the discharge

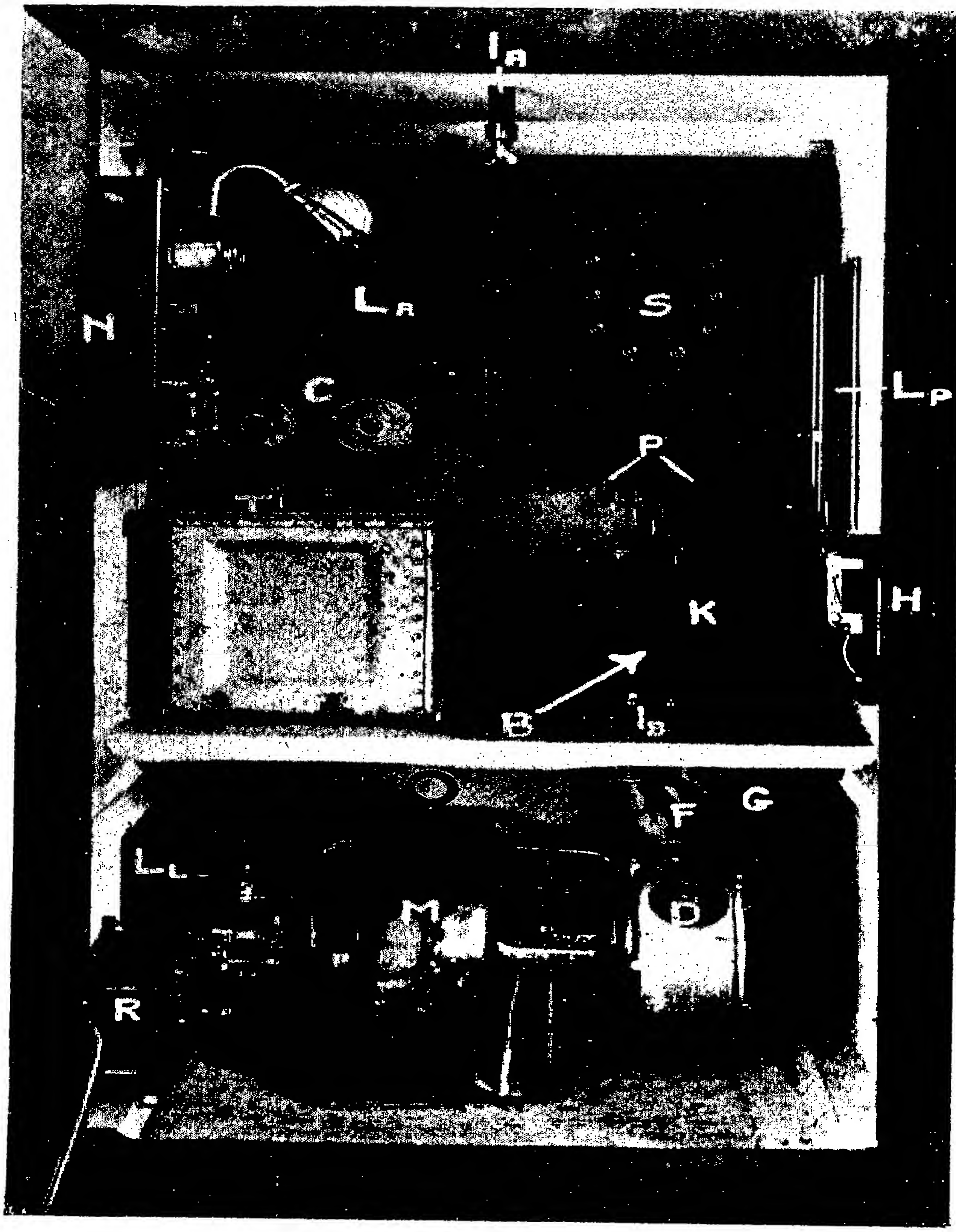


FIG. 127.—1½ K.W. DISC TRANSMITTING SET, FITTED IN SHIP'S SILENCE CABIN.

B, Busbars.—C, Air Core Protector Chokes.—D, Disc Discharger.—F, Flexible connectors.—G, Guard Lamp Board.—H, Main Switch.—IA, Aerial Leading-in Insulator.—IB, Bench Insulator.—IP, Partition Insulator.—K, Condenser.—LA, Aerial Tuning Inductance.—LL, L.F. Tuning Inductance.—LP, H.F. Primary Slider Inductance.—M, Converter.—N, A.C. Switchboard.—P, Jigger Primary Terminals.—R, Field Regulator.

takes place six times every half-cycle, we must endeavour to make the natural oscillation of the charging circuit correspond to it, and not to the alternator frequency, so that at the moment the disc studs come opposite the two electrodes the condenser charge should be tending to surge back again into the circuit independent of what the charging current is doing.

In the paragraph under sub-heading "Low Frequency Iron Core Inductance" in this chapter, it has been shown how the transformer ratio enters into the calculation for tuning the low frequency charging circuit. With the transformer used in the plain discharge circuit it was not possible to reduce the oscillation constant to agree with the 24 stud disc discharge

FIG. 126.—OSCILLOGRAPH, SHOWING THE EFFECT ON CONDENSER CHARGING VOLTAGE OF ASYNCHRONOUS SPARK DISCHARGE.

24-Stud Disc on Shaft of 4 Pole 50 Cycle Converter. Voltage on Spark 11,000. Oscillograph connected across High Tension side of Transformer.

frequency. A transformer with a much lower ratio therefore had to be used, and this had the additional result as mentioned above of still further reducing the potential on the aerial.

Figure 126 shows an oscillograph of the charging voltage at the condenser, as it is effected by the discharge several times per half-cycle, the thin vertical lines being caused by the sudden drop in potential due to the spark.

Figure 127 gives a view of the $1\frac{1}{2}$ k.w. disc transmitting set, complete except for the aerial tuning condenser which has been removed to expose to view the tank transformer. It will be seen that the busbar connectors of the H.F. primary circuit, which in the plain discharge set are entirely above the bench (see Fig. 102), have now to be continued through the bench to connect to the disc discharger terminals below. The effect of

this is to increase the H.F. primary inductance, with the result that, as the circuit still has to generate waves of the same length as before—namely, 300 metres and 600 metres—the condenser capacity has had to be correspondingly reduced, in fact from ·065 mfd., to about ·04 mfd. This new value of condenser capacity in its turn had to be considered, when deciding the new value of transformer ratio found necessary as mentioned above, in order that the output of the set should be maintained at 1½ k.ws.

24 *Stud Disc Discharger.*—This is well shown in Figure 128.

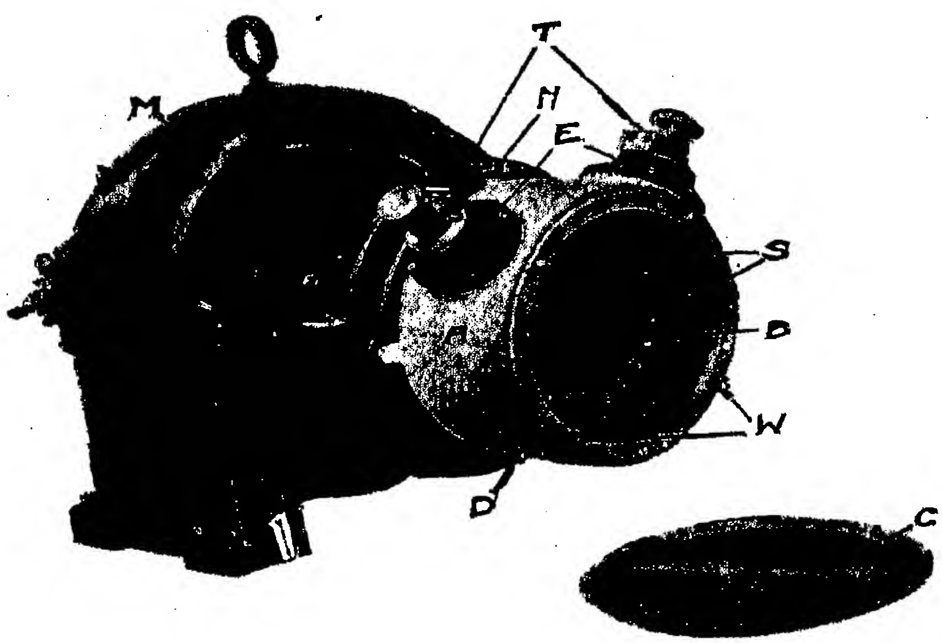


FIG. 128.—24 STUD DISC DISCHARGER ON 1½-K.W. CONVERTER.

A, Aluminium Disc Discharger Box.—B, Brass Ring.—C, Discharger Box Cover.—D, Ebonite Disc.—E, Ebonite Electrode Support.—M, Converter.—N, Nipping Screw.—S, Aluminium Stud Plate.—T, Electrode Terminal.

The electrodes are renewable copper rods, which can be fed down towards the disc studs to compensate for wear, by turning the brass terminal heads. The stud plate S is of aluminium, as this metal gives a better note spark than copper when both the sparking voltage and the power are low. It is clamped between two brass rings, on the periphery of an ebonite disc, which insulates it from the converter shaft. Because the disc is synchronous in speed with the converter, and the electrodes have the same angle between them as the poles of the machine, there is a tendency for the studs to burn unevenly, for each

stud always takes the discharge at the same position in the cycle, and the spark voltage varies according to this position.

The oscillograph Figure 126 shows this effect very well. Owing to the manner in which the disc box which carries the electrodes has been fitted to the machine, only five sparks have taken place every half-cycle instead of six. One stud in every six then has done no work at all.

In order to even up the wear, the relative position of electrodes and studs should be altered occasionally, by slackening the nipping screw N, and rotating the disc box A. If the electrodes are moved round 45° of angle in this manner, the disc studs which previously had most wear will now have least wear, and vice versâ. In certain cases the electrodes have been permanently spaced 45° apart, the machine magnet poles being 90°. The wear on the studs has then been very even. A fan is mounted behind the disc to keep down the temperature of the electrodes. The hot air is driven out through the ventilating holes in the cover C.

1½ *K.W. Condenser, New Type.*—As already explained, the capacity of this condenser for use with the disc discharger, is about two-thirds that of the condenser used with the plain discharger. It contains the same number of glass plates, but fewer zincs, the number of inactive glass plates being greater. Externally, the series parallel fitting for changing the wave length has been improved, by coupling the change-over straps together, extending one of them to form a handle, and fitting spring washers under the terminal nuts, so that by one movement the straps can be altered from the series position to the parallel position without slackening the nuts, good contact at the terminals at the same time being assured (see Fig. 120).

1½ *K.W. Marconi Transformer, Closed Iron Core, Oil Cooled.*—This is a three-limb transformer having a ratio of 75 to 5,000 and 10,000 volts, according to the position of the change-over straps on the lid, and is shown in Fig. 129. The core is made up of lap-jointed stampings. The primary and secondary windings are superposed on the middle limb, being separated by a stout ebonite tube. The secondary winding is in two parts, and each part is divided into a large number of well-insulated sections. In this manner the self-capacity is kept down, and the risk of breakdown is greatly diminished. The change-over straps which cross-connect the secondary terminals, are fitted in the same way as those on the new type

condenser just described. Plug sockets are used for external secondary connections and standard lugs for primary connections.

$1\frac{1}{2}$ *K.W. Air Core Choke, Porcelain Former.*—A protector choke, from its very nature and position in the circuit, is subject to occasional electrical stresses which might under favourable conditions burn the winding and result in fire.

The new type choke is wound with enamel insulated wire on a porcelain former, so that the risk of fire is removed.

It has been already explained that to be effective the resonance wave length of the choke, when joined up in its working

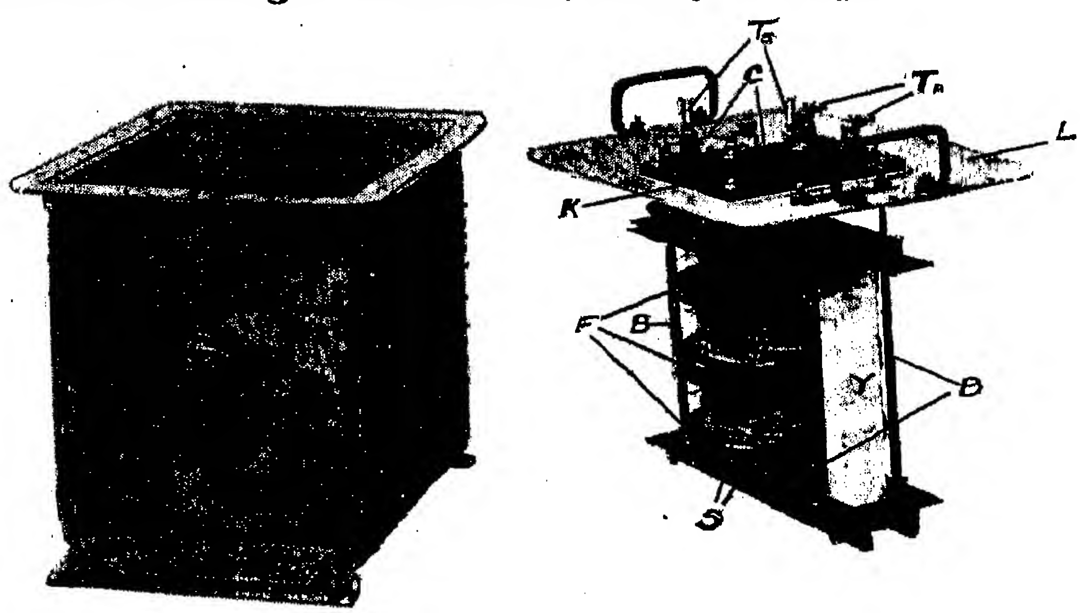


FIG. 129.—$1\frac{1}{2}$-K.W. MARCONI TANK TRANSFORMER, CLOSED IRON CORE, OIL COOLED.

B, Transformer Supporting Bolts.—C, Secondary Change-over Straps.—F, Fibre Plate.—G, Galvanised Tank.—K, Kalanite Terminal Plate.—L, Galvanised Lid.—S, Secondary Sections.—TP, Primary Terminals.—Ts, Secondary Plug Sckets.—Y, Yoke.

circuit, must be considerably more than that of the longest wave generated by the transmitting set. If the wave length does not exceed 600 metres, one layer of winding is sufficient for the purpose, as shown in the general view of the set (Fig. 127). But occasionally, transmitting waves of 1000 metres and 1800 metres are required on special installations. The protector choke is then pile wound in sections, as shown in Fig. 130.

THE RADIATING OR OPEN OSCILLATING CIRCUIT.—This is the last circuit in connection with the transmitting apparatus. It consists of the secondary winding of the jigger, an aerial

tuning inductance, an earth-arrester spark gap, and a tuning lamp.

The Jigger Secondary.—Is a coil of eight turns of cable made up of 21 strands of No. 20 copper wire, each strand cotton-covered. A coil of rope for spacing purposes, is wound between the turns of this winding, the whole arrangement being wound round a square wooden former and afterwards shellaced. Tappings to eight brass plug-sockets, placed on the face of the box in which the secondary is contained, are taken through ebonite insulating bushes. For practical purposes there are seven turns, each one being a trifle more than one actual turn, in order that the tappings may be suitably disposed round the face of the box. The right-hand socket is connected to the turn nearest the primary winding and is marked earth; the inductance of the winding, commencing from this earth terminal and adding one turn at a time, is 1·4, 4, 7·5, 10·8, 16·4, 21 and 25·8 microhenrys. The box containing the secondary is made to slide over the box containing the primary thus permitting a variation of the coupling. A scale on the primary box gives a rough indication of the percentage coupling, but does not, of course, give a close reading, as the coupling also depends on the aerial used, the inductance of the radiating circuit being distributed throughout its length.

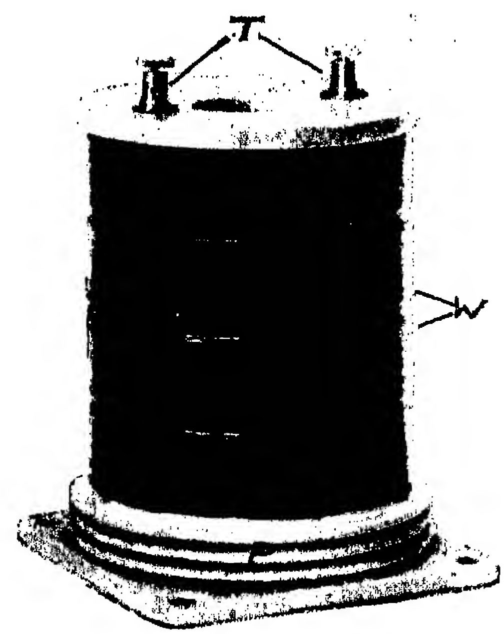


FIG. 130.—$1\frac{1}{2}$-K.W. AIR CORE CHOKE, PORCELAIN FORMER.

P, Porcelain Former.—T, Terminals. — W, Enamelled Wire Winding in four piled sections.

The Aerial Tuning Inductance.—Twenty turns of cable made of 19 strands of No. 20 wire, the whole being vulcanised and braided, are wound round a square wooden former. Tappings are brought from various points through ebonite insulating bushes, to eight brass plug-sockets arranged on the face of the teak containing-box, the number of turns between the various sockets being shown in Fig. 131. It is seen that it is possible to obtain any number of turns from one to nineteen, by taking suitable connections from the sockets. The inductance

measured from the right-hand terminal, and taking one additional section at a time, is 1, 3·25, 8·5, 17, 52, 94·4, and 150·6 microhenrys. As in the case of the jigger secondary, there is really one more turn than is accounted for by the numbers marked on the face of the box, this being so, to provide that all the tappings occur at a fraction over the complete turn, so that they do not come directly under each other. As there is no variable condenser in the open oscillating circuit, the oscillating constant can only be varied by altering the inductance, and this piece of apparatus is designed for such an operation. A long aerial has a larger capacity and inductance than a short one,

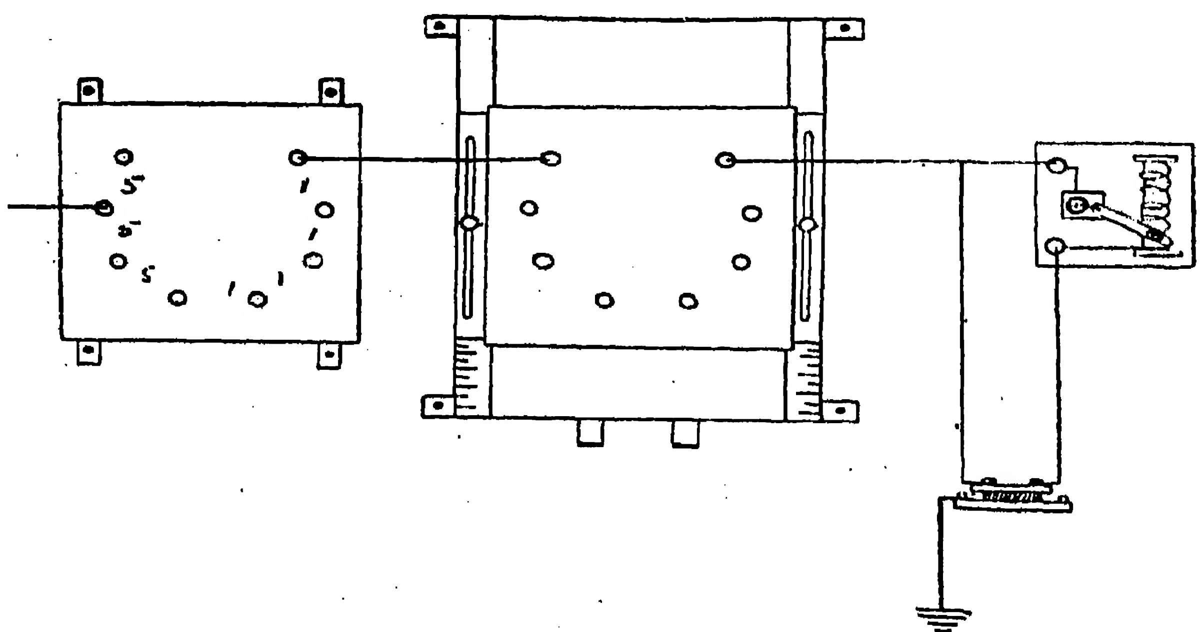


FIG. 131.—Open Radiating Circuit.

so that less of this aerial tuning inductance is required in connection with a long than with a short aerial, for the production of the same wave length.

The Earth Arrester Spark Gap.—This consists of two brass circular plates, separated a distance of one-hundredth of an inch from each other by means of a mica disc, each plate being supplied with four terminal nuts. The upper plate is kept in a rigid position with respect to the lower one, by means of a brass pin fixed in the centre of the latter, which passes through an ebonite bushed hole in the centre of the former, a lock nut being screwed on to the upper extremity of the pin. A circular groove is made in each plate coinciding with the edge of the mica disc, to prevent sparking and burning at the edge of the

mica. A section through a diameter of the arrester is shown in Fig. 132.

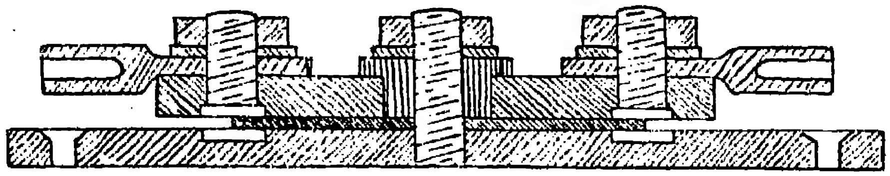


FIG. 132.—Diagram of Earth Arrester Spark Gap, Mica Disc type.

The Tuning Lamp.—This consists of a four-volt lamp, in series with an adjustable inductance coil, mounted on a teak base (Fig. 116). The inductance coil is wound with 8 ft. bare No. 16 copper wire on a grooved boxwood core. One end of the winding is free, and the other end is connected to a terminal on the baseboard. A second terminal is connected to one of

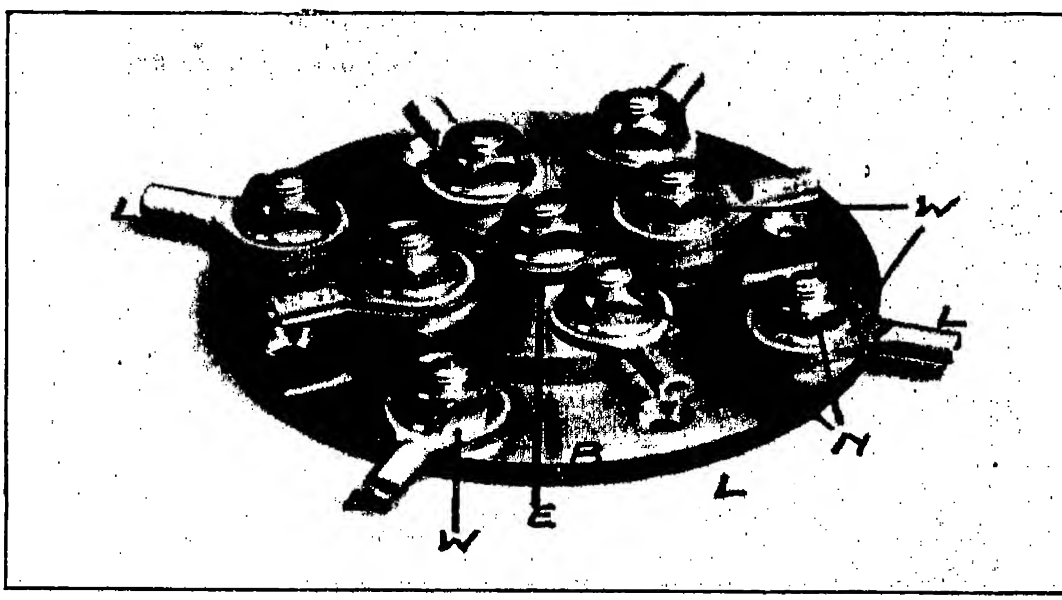


FIG. 133.—EARTH ARRESTER (MICA DISC TYPE).

B, Bottom Plate.—E, Ebonite Bush.—L, Brass Lug.—N, Brass Nut.—T, Top Plate.—W, Brass Washer.

the lamp contacts, the other contact being connected to a pivoted brass arm, the extreme end of which may be moved over the copper wire inductance.

The connections of the various parts of this circuit are shown in Fig. 131. The lower end of the aerial, is connected by means of a special flexible lead known as " 20 amp. flex.," having a wood-handled brass plug at the free end, to the required

socket of the aerial tuning inductance. A second flexible connection, with a similar plug at either end, connects the aerial tuning inductance to the secondary of the jigger, the earth terminal of which is connected by means of the same type of flexible cable to the upper plate of the earth arrester. The lower plate of the earth arrester is connected by means of $\frac{7}{16}$ I.R.V.B. cable to an earth bolt. This latter is a hexagonal brass bar which is reduced and screwed at each end and supplied with nuts and washers. One end of it is screwed into a tapped hole in the iron bulkhead of the ship. If it be convenient to fix a nut on the end of the bolt projecting through the bulkhead, this is done, but very often this end is un-get-at-able and the bolt is merely screwed tight home. The length of the bolt enables it to pass through the thickness of the wood lining of a cabin and still leave the inner end accessible for making the required connection to the earth arrester. The two terminals on the baseboard of the tuning lamp, are connected to two points, about 6 ft. apart, on the wire connecting the earth terminal of the jigger to the upper plate of the earth arrester.

The aerial and its accessories will be dealt with in a separate chapter, at the end of which instructions for tuning will be found.

Short Wave Condenser.—In cases where the aerial is so long that its natural frequency does not admit of a wave length of 300 metres without taking out too many turns of the jigger secondary, a condenser is connected between its lower extremity and the upper plate of a separate earth arrester spark gap.

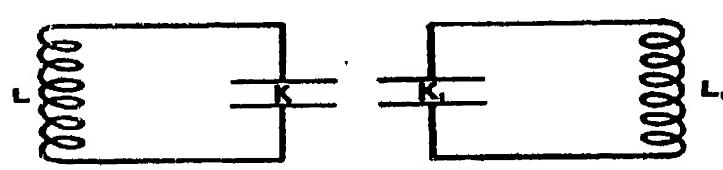


FIG. 134.—Two Separate Closed Circuits.

The following explanation may help to make clear the use of this extra condenser.

If the two circuits shown in Fig. 134 have the same frequency, the oscillation constants are equal, or—

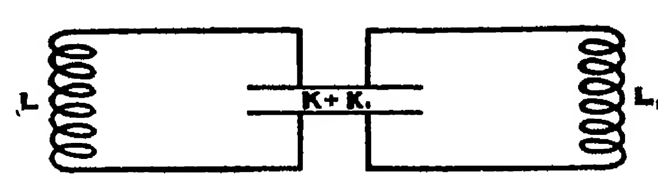


FIG. 135.—Same Circuits as in Fig. 134 joined in parallel.

$$\sqrt{LK} = \sqrt{L_1 K_1}.$$

If the two circuits be now joined, as in Fig. 135, the total capacity of the condenser is equal to the sum of the separate

capacities ; or, taking a very simple case in which the capacities and inductances in each circuit are equal, the capacity of the second arrangement becomes $2K$.

The inductances L and L_1 are in parallel, and consequently

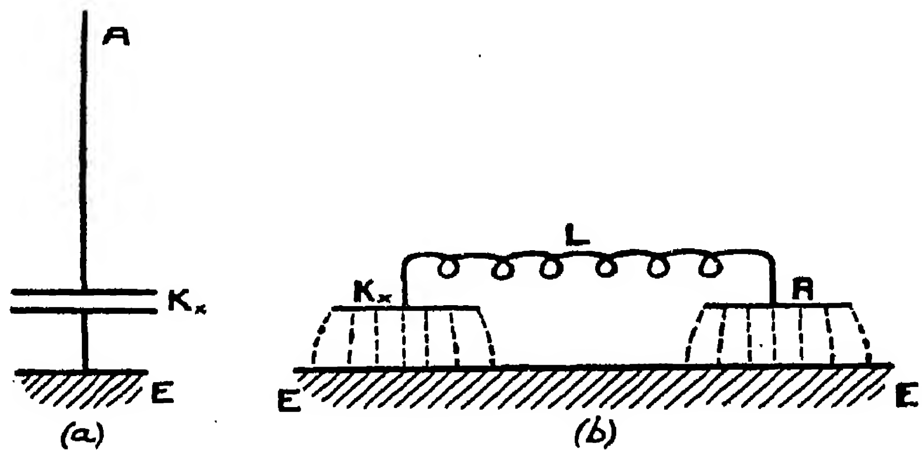


FIG. 136.—Aerial Circuit with Condenser in Series.

only half the total current passes through each. If L is equal to L_1 (as must be the case if K equals K_1 and the two circuits possess the same frequency), the total inductance becomes $\frac{L}{2}$ and the oscillation constant for the circuit is

$$\sqrt{2K + \frac{L}{2}} = \sqrt{LK}$$

In short, if two circuits of the same frequency be joined as shown, the resultant circuit still possesses the same frequency. In the case quoted, two closed circuits have been dealt with.

If A, Fig. 136 (*a*), represents an aerial with a natural frequency fitting it for the production of a fairly long wave, the insertion of a condenser, Kx, at its lower extremity, will reduce the total capacity and render it suitable for the production of a shorter wave.

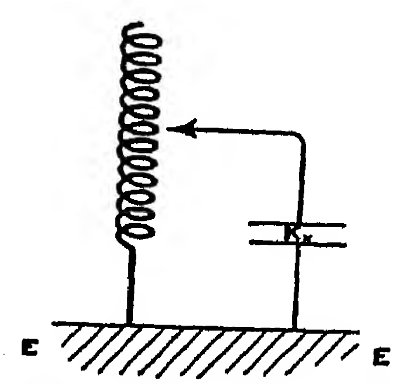


FIG. 137.—Jigger Secondary with Circuit completed through Condenser and Earth.

An aerial is a path for high frequency oscillations, in which capacity to earth and inductance are distributed along its whole length.

It may aid us to understand its behaviour, if we represent

the inductance part of it—*L*, Fig. 136 (*b*)—as being distinct from the capacity part—AE, Fig. 136 (*b*).

By suitably fixing the value of the condenser, Kx, the aerial circuit may be tuned to a 300-metre wave.

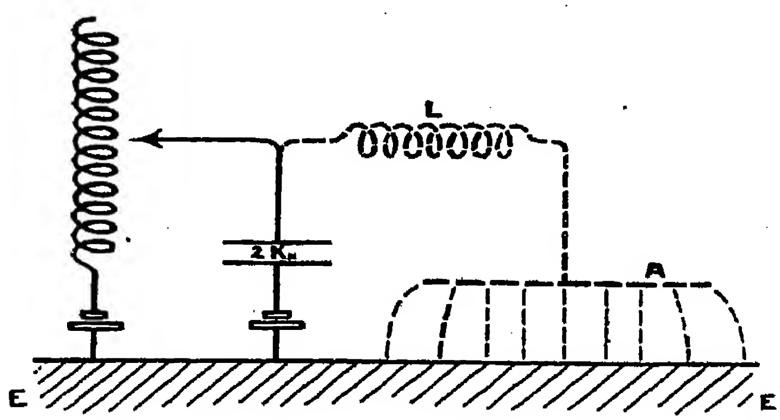


FIG. 138.—Combination of FIGS. 136 and 137.

Next the jigger secondary by itself can be tuned with the aid of another condenser, to give a 300-metre wave.

Fig. 137 shows the circuit completed through the earth, but in practice the wires may be joined at the earth-arrester during the test.

Also, in Fig. 137 this second condenser is made equal to the first, Kx, and the circuit adjusted to 300 metres by using more or less inductance. It is better, however, to use the

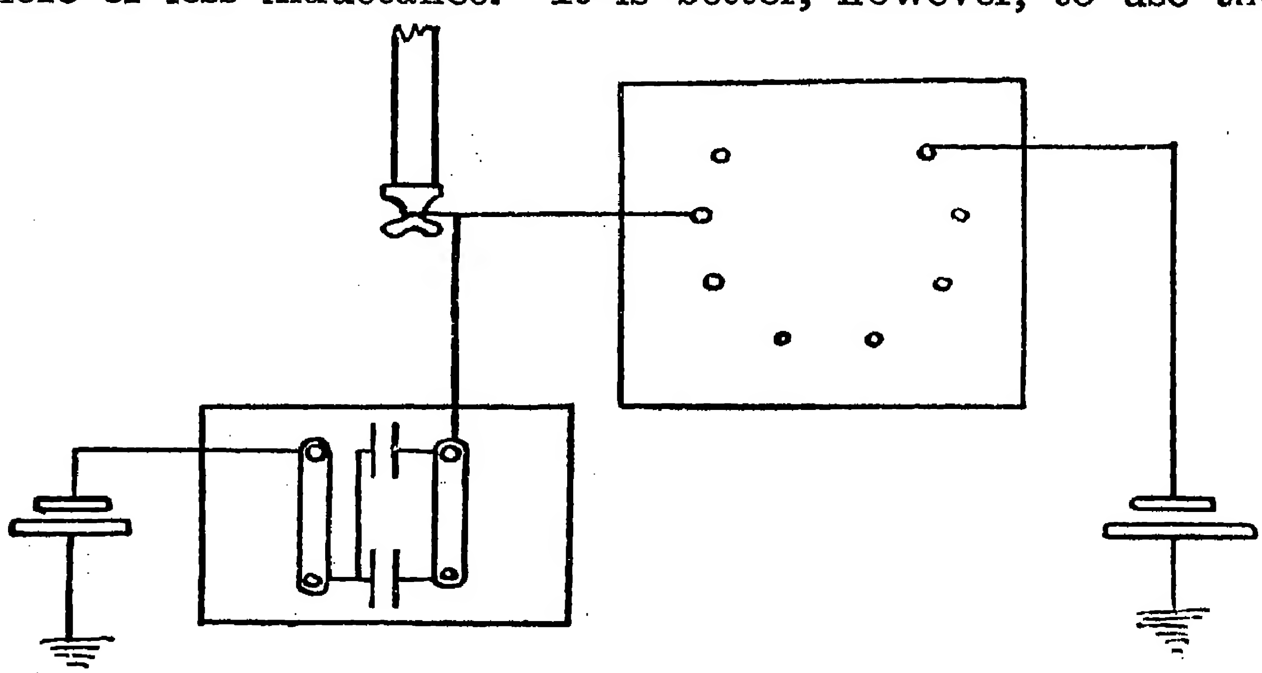


FIG. 139.—Open Radiating Circuit (Short Wave Adjustment).

jigger-secondary, neither more nor less, and to adjust by altering the second condenser.

The two 300-metre circuits thus obtained, may be joined together just as in Fig. 135, by putting the two condensers in parallel and connecting aerial and earth as shown in Fig. 139,

or its equivalent, Fig. 138. The complex circuit thus formed will still radiate a 300-metre wave, which will be excited in it by the action of the jigger-primary on the jigger-secondary.

Use of Separate Arrester.—It is seen that two earth arresters are used, and the reason is fairly obvious. If only one arrester were used the arrangement would be as shown in Fig. 140. In this case a closed oscillating circuit consisting of the whole condenser and jigger secondary L is formed, and in the event of received currents possessing the same frequency as this circuit, they would oscillate in it instead of passing through the receiver to earth.

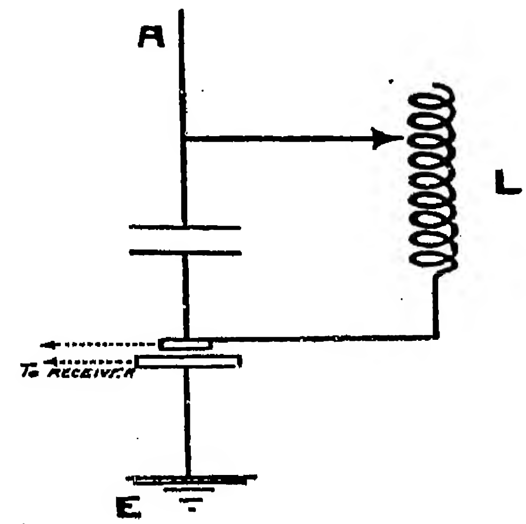


FIG. 140.—Same as in Fig. 139, but incorrectly connected to one Arrester.

The short wave condenser is of the same type as the main condenser, but it has to be specially built up to the capacity required for the particular aerial with which it is to be used. (See paragraph on Tuning Short Wave Transmitting Apparatus.)

RECEIVING APPARATUS. — The receiving circuit includes the magnetic detector, the multiple tuner, a pair of telephones, and a telephone condenser. A crystal receiver known as type No. 20, to be used with the multiple tuner, alternative to the magnetic detector, has recently been added to many ship installations.

The Magnetic Detector.—This instrument is shown in Fig. 141. A, and B, are two ebonite discs grooved round the peripheries, B being mounted on a spindle forming part of a clockwork driving mechanism, contained in the body of the instrument, and A being mounted on a brass plate, C, capable of sliding along a bed piece, D. The adjustment is effected by turning the screw, E, which is used to put the necessary tension on a continuous band of stranded soft iron wire, F. This band is made up of 70 strands of No. 40 S.W.S. (single wound silk) iron wire, twisted into the form of a small rope which is rotated by the clockwork at a rate of about 1·6 metres per minute. This band passes through the centres of two sets of coils, the primaries being marked P, and the secondaries S. The ends of these coils are connected to four

terminals on each side of the instrument, the secondary winding being connected to the inner pair of terminals in each case.

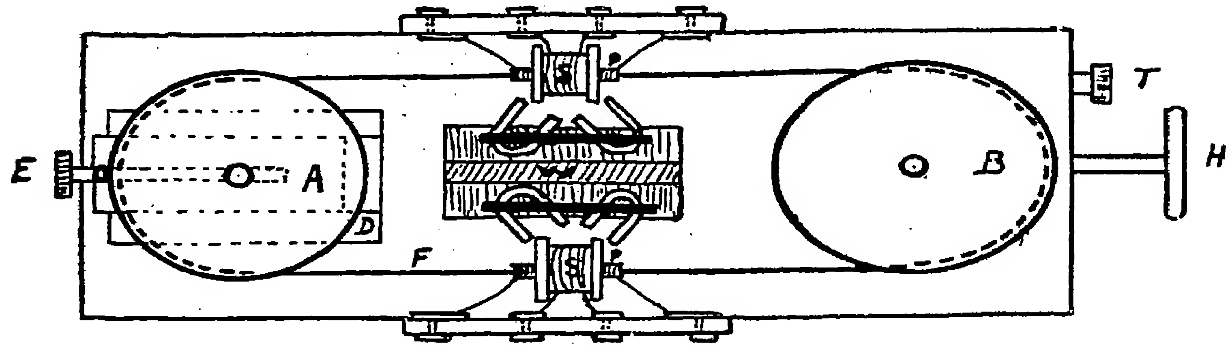


Fig. 141.—Magnetic Detector in Plan.

Between these two sets of coils a wooden block, W, carries four horseshoe magnets, two on either side. The usual position of the magnets with respect to the coils is shown in Fig. 143 (*a*), where it is seen that the like poles are together. This arrangement results in a slight hissing sound being produced in the telephones all the time the band is moving. If the magnets be rearranged, as in Fig. 143 (*b*), this hissing or breathing effect is eliminated and at the same time the sensitiveness of the receiver is slightly lessened. The matter of arrangement is largely a matter of personal choice. Many operators claim that the breathing effect renders the reading of very weak signals difficult and that the latter arrangement is the better. But other operators prefer the former arrangement, because, while they do not agree with those who claim breathing to be an obstacle in the way of the reception of weak signals, the cessation of breathing when no signals are coming through, at once indicates that the clockwork has run down, or that the band has stopped from some other cause, or that there is a faulty connection in the circuit.

H is the handle for winding up the clockwork, which will drive the band round for an hour and three-quarters for one winding-up. The clockwork is specially designed for even and silent running. Means of stopping or starting the clockwork is provided by the brass knob, T.

The primaries are wound over small glass tubes, and are made of No. 36 D.W.S. (double wound silk) copper wire. They are wound for a distance of about 2 centimetres over the tube, this giving them a resistance of between 2 and 3 ohms, and

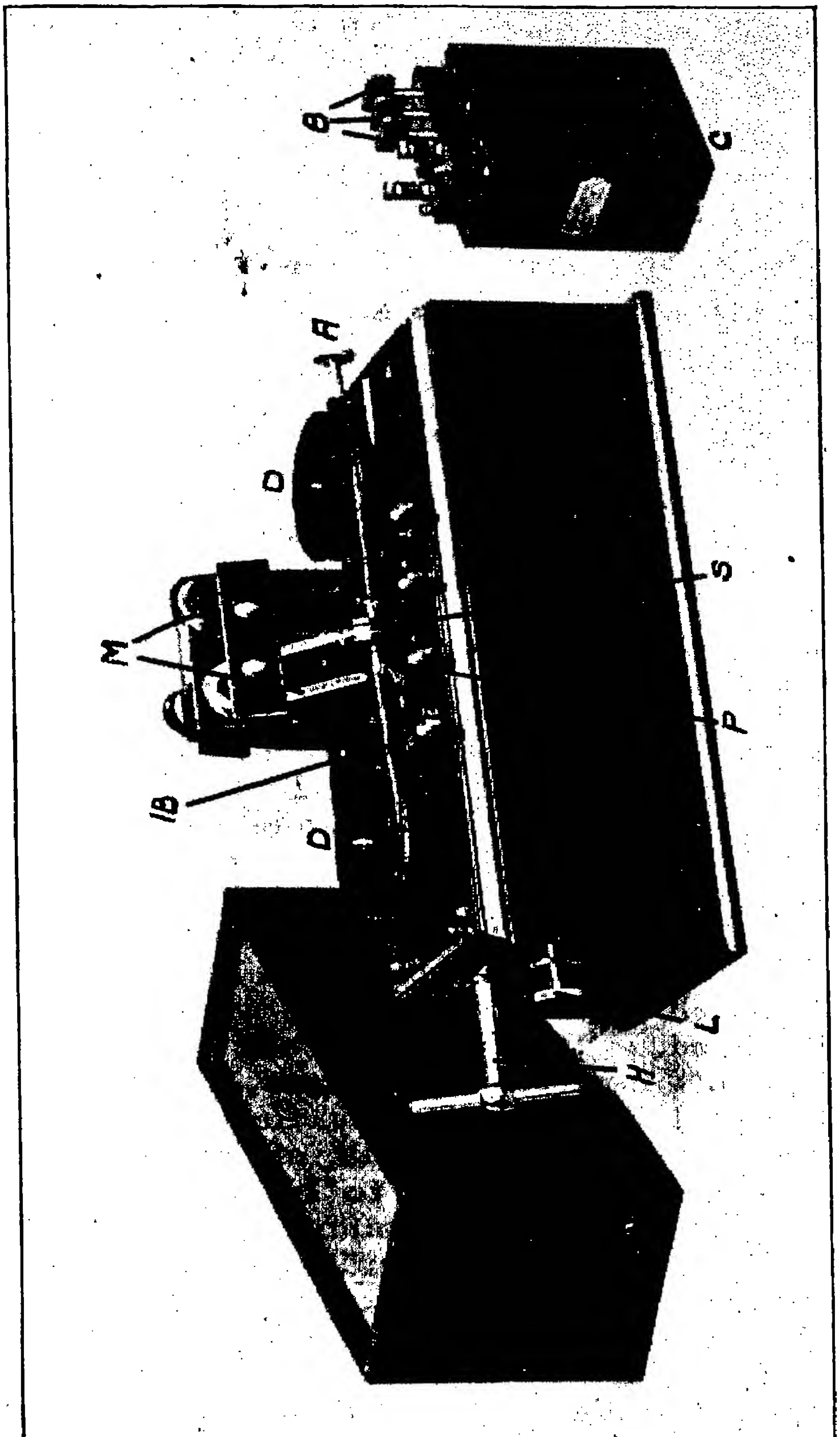


FIG. 142.—MAGNETIC DETECTOR.

A, Adjusting Screw for varying Tension of Iron Band.—B, Telephone Condenser Plugs.—C, Telephone Condenser.—D, Ebonite Discs.—G, Glass-fronted Cover.—H, Winding Handle for Clockwork.—IB, Iron Band.—L, Clockwork Control.—M, Magnet.—P, Primary Coil.—S, Secondary Coil.

an inductance of about 30 microhenries. Each secondary coil is wound on an ebonite bobbin to a resistance of about 140 ohms, which is about the same resistance as that of the

FIG. 143.—Detector Magnet Arrangements.

telephones which are used with the detector. The action of the magnetic detector has already been explained. Only one side is used at a time, the second set of coils and magnets being provided as a stand-by in case of a breakdown in the other set. The primary terminals are connected by means of a bare No. 10 copper wire to the terminals marked "Detector" on the multiple tuner.

The Multiple Tuner.—This instrument contains the variable inductance and capacity for the aerial receiving circuit, the whole of an intermediate circuit, and the variable inductance and capacity for the detector tuning circuit. The inductance coils are contained in a teak box with an ebonite top and front. On the top are three disc condensers, one for each circuit. Also a two-way change-over switch, and a micrometer spark-gap. To the left-hand side of the front of the instrument is an ebonite handle carrying a brass arm, capable of rotation over a set of brass studs set in the form of a circle, which enables the inductance in the aerial circuit to be adjusted. To the right of this handle is another, which is so connected by means of ebonite coupling strips to three brass arms, that these arms may be moved simultaneously over three sets of brass stops, thus enabling proportionate adjustments to be made in each of the three circuits with a single movement. This is called the Tuning Switch. Each of the two handles are calibrated, the aerial inductance being marked in microhenrys, and the tuning switch showing the limits of the receivable wave lengths on the respective stops. On the right-hand end of the instrument a third ebonite handle is mounted, called the intensifier handle, marked in degrees through one quadrant on its periphery. This handle is used to vary the relative positions

of the inductances in the intermediate circuit, with respect to the inductances in the aerial and detector circuits, or, as already explained, to vary the coupling between the circuits. The internal connections are shown in Fig. 144, but in order

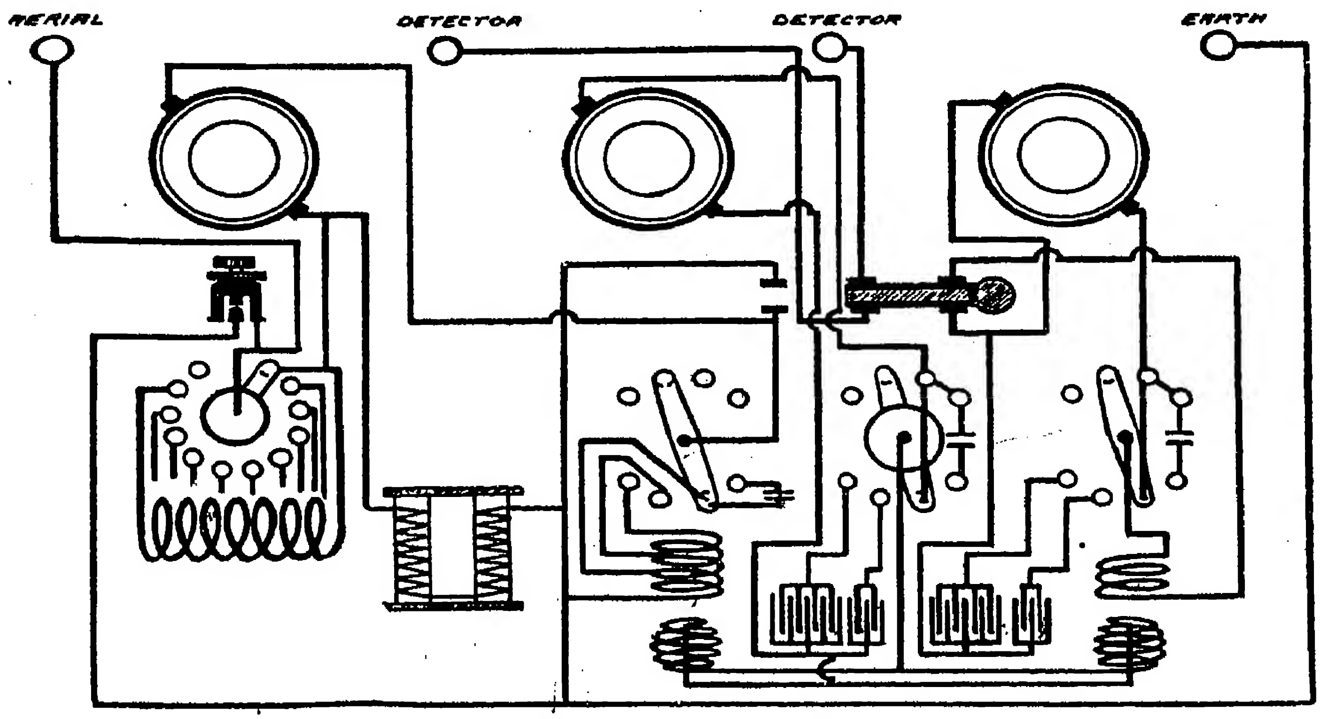


FIG. 144.—Multiple Tuner Connections.

to understand more easily the different circuits, a less involved drawing is given in Fig. 146.

Taking the diagram of range 2, for instance, the aerial circuit consists of the aerial, the variable inductance, L, the variable condenser, K_1, and the variable inducing inductance, P_1, and a connection to earth. From the junction of the aerial and the inductance L, a lead is taken to a micrometer spark-gap to earth, M; and from the junction of the inductance L and the variable condenser K_1, a coil of high inductance value, R (of the order of 80,000 microhenrys), affords a second path to earth.

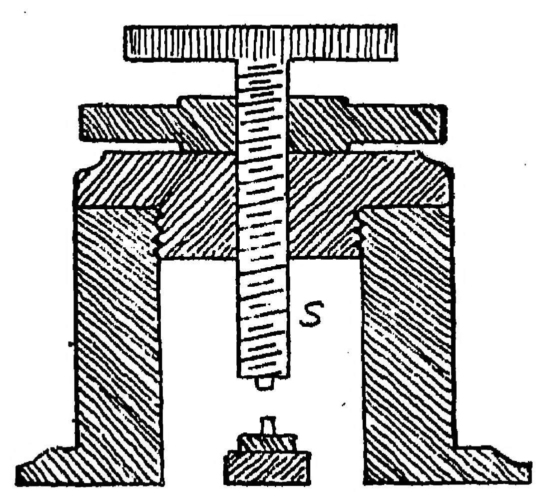


FIG. 145.—Section of Micrometer Spark Gap (Multiple Tuner).

The use of this gap, and inductive shunt, is to prevent the accumulation of a heavy static charge on the aerial. Small

charges leak to earth through the shunt coil, and heavy sudden charges jump the spark-gap to earth, this being a path of less effective resistance, or impedance, than the path through the oscillatory circuit. The inclusion of these circuits in the apparatus, is necessary to protect the aerial tuning condenser from being broken down, and the inductance coils from having their insulation damaged. A section of the micrometer spark-gap is shown in Fig. 145. The pitch of the thread on the screw S is such, that one complete revolution moves the contact through one-hundredth of an inch. The screw has a left-handed thread, and may be set by screwing S down until the contacts meet, and then giving it one complete turn back.

The intermediate circuit consists of the two fixed inductances, S_1 and P_2, joined in parallel across the variable condenser, K_2. The detector circuit consists of the fixed inductance S_2, the variable condenser K_3, and the primary winding of the magnetic detector, connected to the tuner at the terminals marked D.

A variation of the aerial tuning inductance handle, changes the point in L at which the tapping B is taken off.

A variation of the position of the intensifier handle, alters the position of the coils S_1 and P_2 with respect to the coils P_1 and S_2; and an alteration of the tuning switch handle, produces variations in each circuit as shown in ranges 1, 2, 3, and 4, Fig. 146.

With the tuning switch on the first stop, a small block condenser is placed in series in each circuit, thus reducing the capacity in each to dimensions suitable for the reception of short waves. On the second stop, these small block condensers are cut entirely out of each circuit. Contact with the third stop introduces inductance in the aerial circuit, and places small block condensers in parallel with the variable condensers in the intermediate and detector tuning circuits, thus providing for the reception of longer waves. The fourth stop increases the value of this added inductance and capacity. The wave-ranges for the respective stops are given in the diagrams. A careful consideration of the more complicated diagram of the actual connections will show how the simplified drawings have been made. The switch on the top of the instrument is used to change over from a "stand bi" position, when waves of widely varying length are audible, to a "tune" position, which is done when it is desired to cut out

all other signals than those of the wave length whose reception is required.

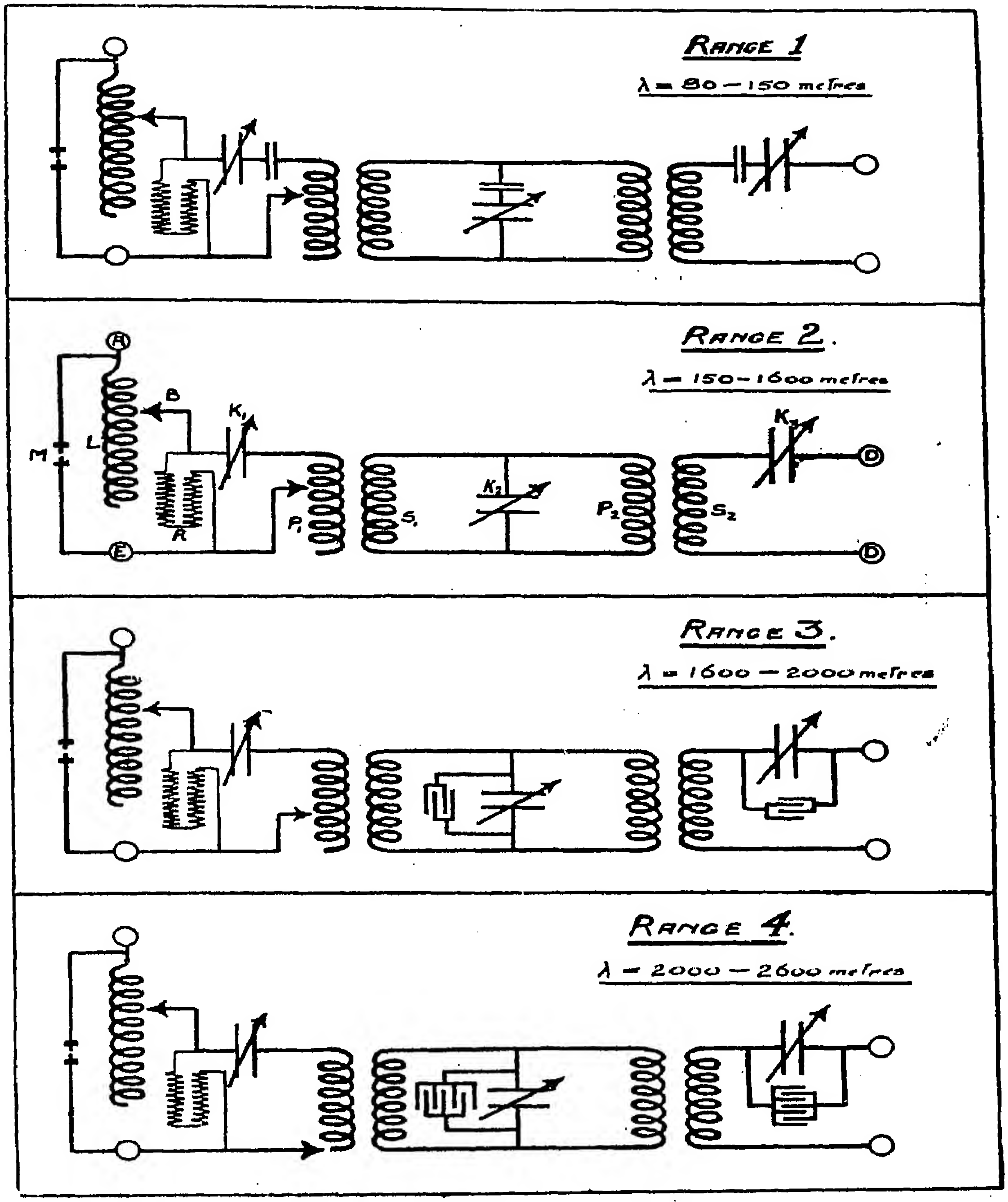


FIG. 146.—Connections of M.T. for Various Adjustments.

A simple diagram showing how this switch is connected, is shown in Fig. 147. It is seen that on the "stand bi" side, the magnetic detector is directly in the aerial circuit, and that

the operation of throwing over the switch places it in the detector circuit.

The tuner is designed for a range of from 80 to 2,600 metres, or say from 300 to 8,000 feet. If the capacity of a standard Leyden jar be taken as 1,000 centimetres, the maximum capacity of each of the three variable condensers is ten jars. A scale on the top of each condenser is marked accordingly, and is subdivided into divisions of one-tenth of a jar. The block condensers placed in circuit by means of the tuning switch, increase the capacity in the intermediate and detector circuits to a maximum of 30 jars. If the capacity

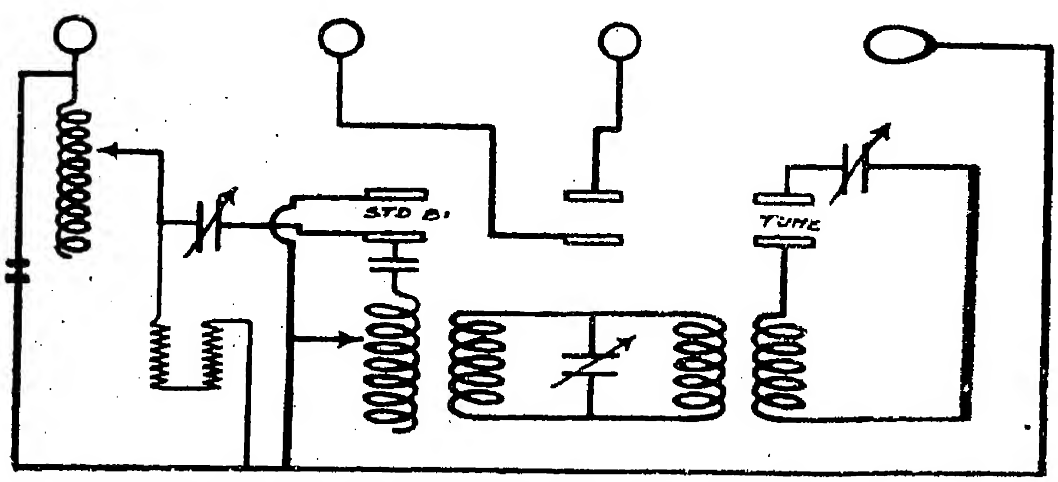


FIG. 147.—Change-over Switch Connections M.T.

be reckoned in jars, and the inductance in microhenrys, the formula for the calculation of wave length in feet is

$$\lambda = 206\sqrt{\text{jars} \times \text{microhenrys}}.$$

As already stated, the two terminals marked "Detector" are connected to the ends of the primary of the magnetic detector. Two other terminals with which the top of the instrument is provided, are marked "Aerial," and "Earth," and are connected by means of 2½ ampère flexible wire, to the upper and lower plates respectively, of the earth arrester spark-gap.

The use of the arrester is now apparent. The received currents being extemely weak, are unable to break down the air resistance of the small gap, and run to earth through the whole of the receiving circuit. The powerful currents developed in the aerial during transmission, are at a high enough voltage to jump this small gap, the latter offering much less impedance than is offered by the coils in the receiving circuit.

It is seen, therefore, that the arrester obviates the necessity for a switch, for the purpose of changing over from sending to receiving; or perhaps it would be better to state that it acts as an automatic switch, for this purpose.

Disc Condenser (*Variable*).—The variable condensers mounted on the multiple tuner are of the most compact form in existence, a variable capacity up to ten jars, or 10,000 centimetres, being contained in a flat cylinder 4 inches in diameter, and 1¾ inches in height. The conductors consist

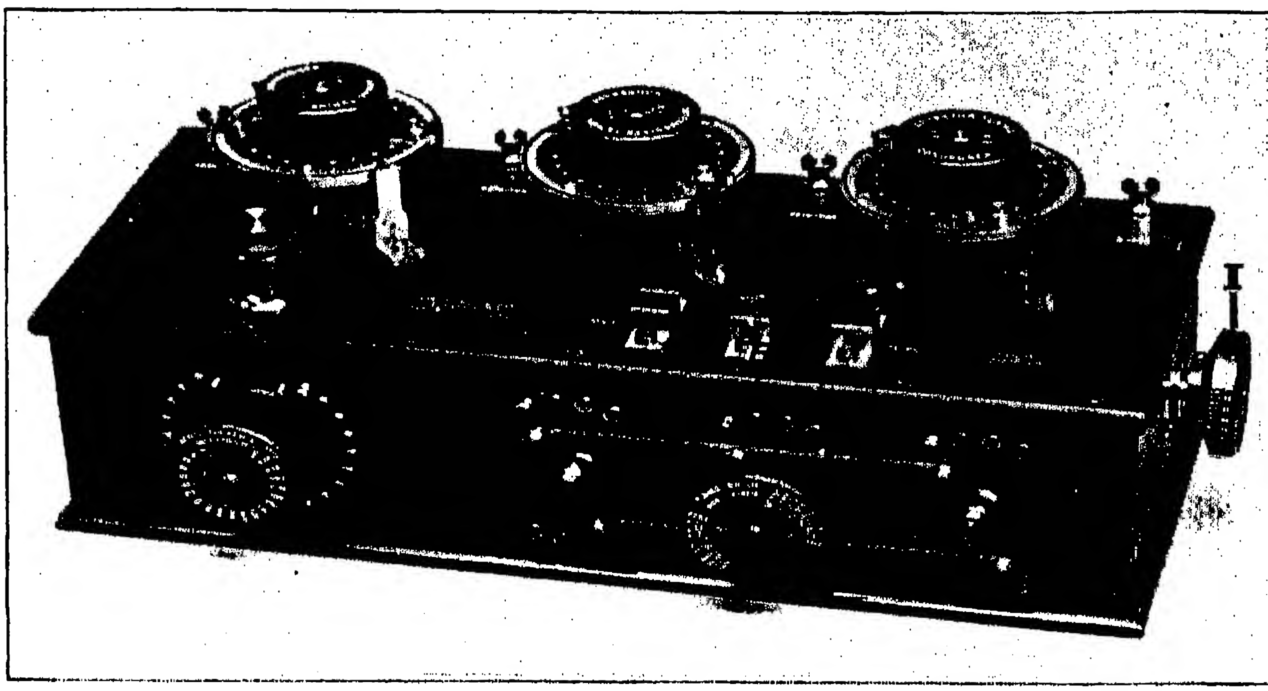
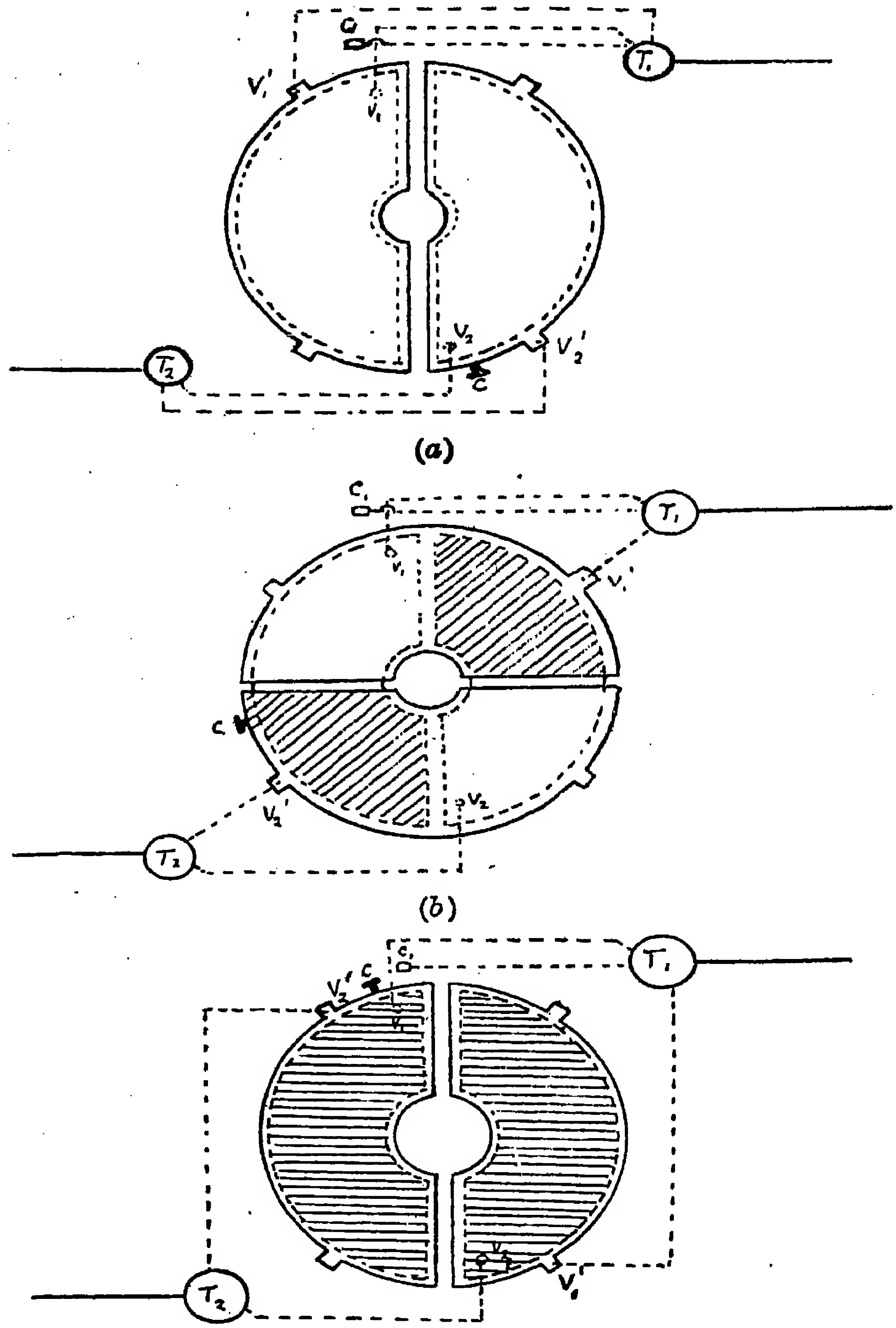


FIG. 148.—MULTIPLE TUNER.

A, Aerial Inductance Handle.—B, "Stand bi" Change-over Switch.—I, Intensifier Handle.—KA, Aerial Condenser.—KI, Intermediate Condenser.—KD, Detector Condenser.—L, Lock Nut.—M, Micrometer Spark-gap.—S, Adjusting Screw.—T, Tuning Switch Handle.

of two sets of interleaving zinc vanes, and the dielectric consists of a number of thin circular sheets of ebonite. In each set, half the vanes are held in a fixed position in the container, whilst the other half are all capable of being turned through 180 degrees, by the movement of an ebonite handle mounted on the top of the cylindrical container. Figs. 149 (*a*) (*b*) and (*c*), show the disposition of the movable vanes with respect to the fixed vanes, for capacities of zero value, half the total value, and the total value respectively. T_1 and T_2 are the main terminals of the condenser, the former being permanently

connected to the movable vanes at V'_1 and to the fixed vanes at V_1, while the latter is connected to the movable vanes at



FIGS. 149 (*a*), (*b*), and (*c*).—Disc Condenser, Explanatory Sketches.

V'_2 and to the fixed vanes at V_2. In Fig. 149 (*a*), it is seen that both the movable and fixed vanes connected to the terminal T_2 are in the right-hand bank, and the movable and fixed

vanes connected to the terminal T_1 are in the left-hand bank. Thus the capacity of the condenser in this position is practically zero, the effect across the opposing edges of the vanes along the centre being negligible. If the vanes V'_1 and V'_2 be moved together into the position shown in Fig. 149 (*b*), they interleave with the fixed vanes connected to the opposite terminals, the resulting effective capacity areas being shaded in the figure. If the moving vanes be taken through another 90 degrees, as shown in Fig. 149 (*c*), it is seen that the whole areas of the vanes are active, as those connected to one ter-

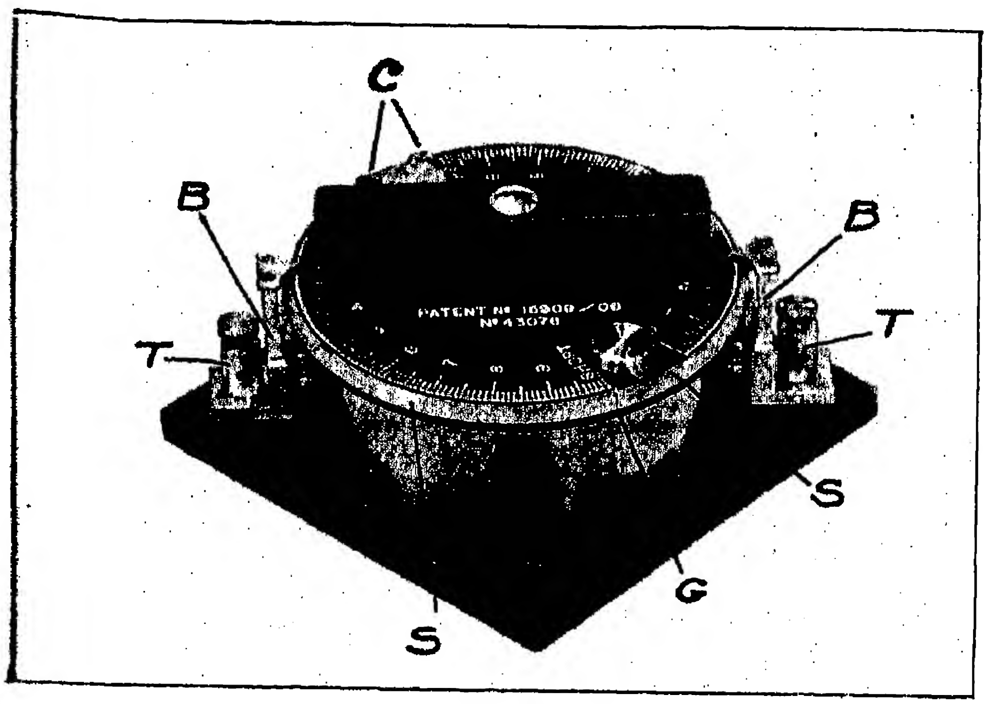


FIG. 150.—EBONITE DISC CONDENSER (ADJUSTABLE).

B, Index and Brush Standards.—G, Protector Gap.—S, Movable Vanes Contact Strips.—T, Terminals.

minal completely interleave with those connected to the other. This, of course, means that the condenser has a maximum capacity, and it is easily seen that a condenser of this type is continuously adjustable, so that extremely small variations of capacity may be obtained.

A brass contact piece, C, is attached to the movable vanes connected to the terminal T_2, and if the handle be turned a little beyond the maximum capacity point, C makes contact with a stop C_1, which is permanently connected to the terminal T_1, thus shorting the condenser. One of these condensers, mounted separately for independent use, is shown in Fig. 150.

To each of the terminal blocks T, is connected a set of fixed vanes; and each standard B, supports at the top an index which overhangs the scale, and at the base a flexible vertical brush which can be seen bearing on a brass contact strip S, that connects to one set of moving vanes.

Between the two contact strips is a safety spark gap, G, having a width of ·01″. The ebonite below and behind the gap is cut away to increase the surface insulation. One only is shown in the illustration; there is, however, a second diametrically opposite to it. The gaps protect the sheets of thin ebonite dielectric from puncture when exposed to excess voltage. Care should be taken to keep them free from dust, and no grit should be allowed to get under the brush contacts. In the actual condenser illustrated, the short-circuit is arranged by the brushes bridging the gaps G. The stops C are simply screwed into the ebonite; they do not connect to the moving vanes.

The Telephone Condenser.—This condenser, which is shown

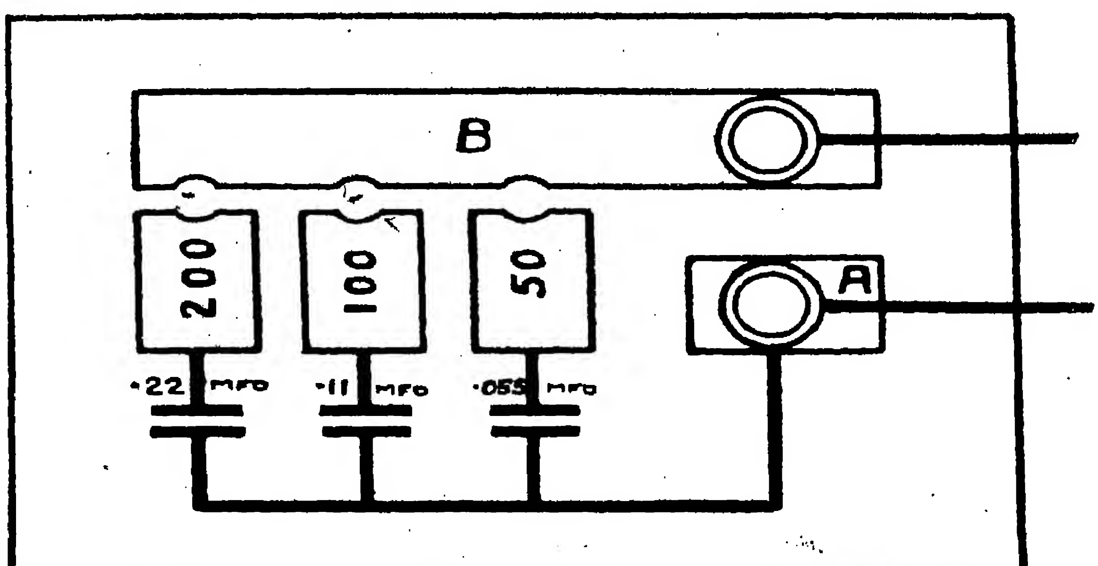


FIG. 151.—Telephone Condenser.

in Fig. 142, has sheets of tinfoil as conductors, the alternate sheets being separated from each other by a mica dielectric. The condenser is divided into three parts, varying amounts being placed in the circuit by means of brass plugs and sockets. A sketch of the connections is shown in Fig. 151. Five brass blocks are disposed on the ebonite top of a teak box as shown. Three condenser groups of ·055, ·11 and ·22 microfarads respectively, are fixed in paraffin wax in the wooden box.

One side of each group is connected to the block A, the other sides being connected respectively to blocks marked 50, 100, and 200 respectively (Admiralty units). Three brass plugs are provided, by means of which any separate condenser, or combination of condensers, may be joined across the terminals, by plugging on to block B. Seven different values are thus obtainable. The capacity is large in comparison with the outside dimensions of the instrument, because, as it has to stand only low pressures, the distance between the conductors or the thickness of the dielectric need only be small, thus allowing for the placing of a large number of sheets providing a large area in a small space. The terminals of this condenser, are connected to the secondary terminals of the magnetic detector, by means of 2½ ampère flexible wire, and its use is to sharpen up the tone of the signals in the telephone, and generally to improve reception. Except in the case of very high note signals, improvement by resonance need not be expected.

The Telephones,—are connected either to the terminals of the above condenser, or to the secondary terminals of the detector.

A brief explanation of the telephone is here necessary. Sound is a sensation excited in the ear by the vibratory motion of bodies.

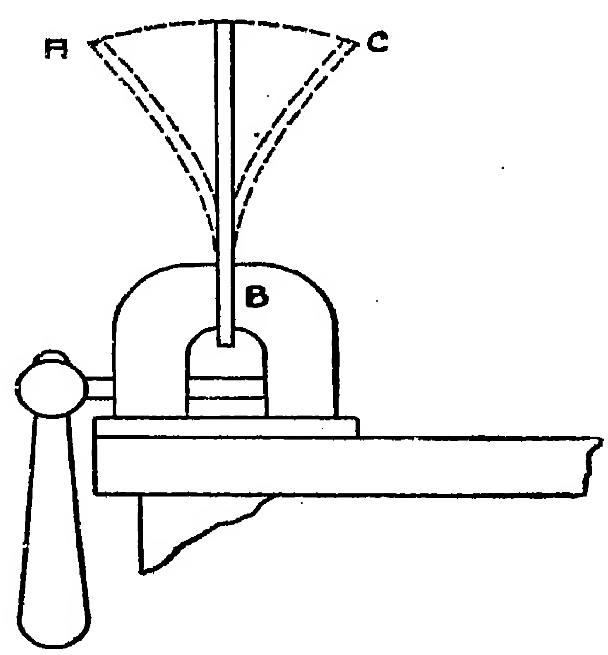


FIG. 152.—Production of Sound Waves.

If a flat steel spring be fixed in a vertical position in a vice, as shown in Fig. 152, and the free end of it be displaced so that it takes up the position shown by the dotted line AB, on releasing it a vibratory motion will follow. The end A will pass backwards and forwards along a gradually decreasing arc, AC. During its first movement to the right, it compresses the air on its right-hand side, and causes a state of rarefaction on its left-hand side. A reverse movement has exactly the opposite effect. As long as the spring continues to vibrate, waves of rarefaction and compression are propagated, the frequency of these waves or the number of complete vibrations per second,

determining whether they are audible or not. If the frequency be anything between 30 and 20,000 per second, audible sounds are produced. The telephone is an instrument capable of producing waves in the air of such a frequency. A disc of thin soft iron, varnished to prevent rusting, takes the place of the spring just described, and it is set in vibration by fluctuations in the intensity of a magnetic field. Fig. 153 shows an electro-magnet with its two poles in close proximity to a disc of soft iron, D, which is firmly clamped in position by its edges. The core of the magnet is permanently magnetised and exercises a force of attraction on the disc. If a current be passed through the coils wound round its pole pieces, this force of attraction is increased or decreased according to the direction of the current. If the force be increased, the centre of the disc is pulled towards the magnet; and if the force be decreased, it is released to some extent. If, then, rapid alternations of current, or intermittent

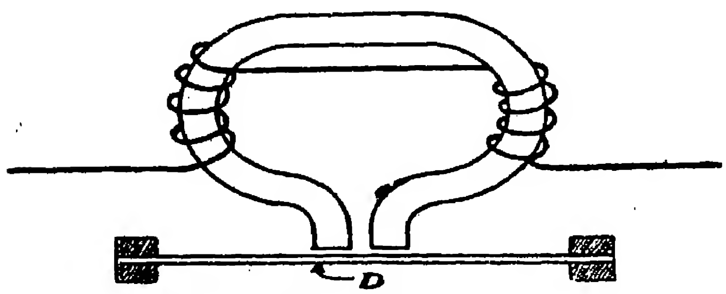


FIG. 153.—Theoretical Telephone.

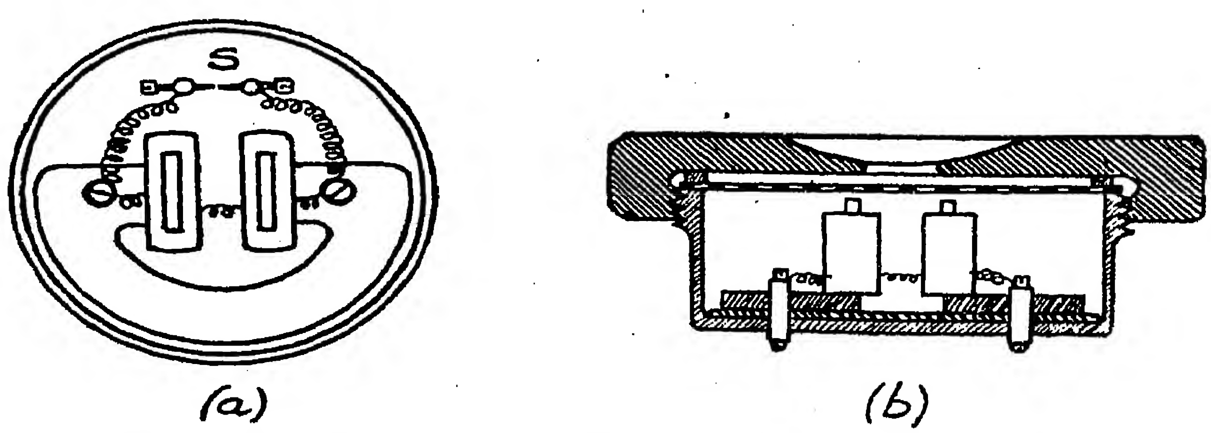


FIG. 154 (*a*) and (*b*).—Plan and Section of Telephone (Watch Pattern).

unidirectional currents, be passed through the windings, the disc (or diaphragm, as it is called) is caused to vibrate; and if the frequency of the vibrations be within the limits stated above, they will produce the sensation of sound in the ear. Figs. 154 (*a*) and 154 (*b*) show a plan and section of the type of telephone receiver used in a wireless installation. On account of its shape, such a receiver is called a watch receiver.

Two complete watch receivers are connected in series at the ends of a steel or aluminium strip spring, to form the telephone head-gear. As the space available is very small, the wire used in the coils of the electro-magnets must of necessity be very thin, in order to obtain the necessary ampère-turns required for the high degree of sensitiveness of the telephone. In the low resistance telephones used in connection with the magnetic detector, the wire is insulated with silk, but where a much greater number of turns is required, as in the case of the telephones of from two to eight thousand ohms resistance used with a valve or crystal receiver, the insulation usually consists of a coating of enamel, as space is thus economised. In the high resistance telephone a pair of protective spark points is often included, as shown in Fig. 154 at S, as a guard for the coil windings against excess voltage due either to direct application, inductive kick on suddenly breaking circuit, or high frequency surge—all tending to damage the insulation. Again, where enamelled wire is used, the interior of the case is filled with paraffin wax, further to ensure good insulation.

Telephone Short-Circuiting Device.—Two leads of 2½ ampère flexible wire, are taken from the two brass springs fitted with contacts, already mentioned as being mounted on the manipulating key, either to the telephone condenser or to the secondary terminals of the magnetic detector. If the main break of the key, and the break between the two small contacts be properly adjusted, the latter will short-circuit the telephone just before the condenser in the transmitting circuit discharges, thus preventing the loud sounds of the transmitted signals being heard in the telephones. This prevents the telephones and the operator's ear being rendered insensitive. At the same time it is possible during the intervals between each transmitted dot and dash, to detect any effort on the part of the corresponding station to ask a question.

Adjustment of Receiving Circuit.—When not in actual communication with any particular station, the operator always listens with the change-over switch on the "stand bi" position. With an aerial of normal length, he "stands bi" with the aerial tuning condenser shorted, and with none of the aerial tuning inductance in the circuit. If the aerial be a long one, a certain amount of condenser is used when standing "bi," and if it be a short one, a certain amount of inductance is necessary in the circuit. Very often an adjustment

of the aerial inductance and capacity, is all that is necessary to render the required signals distinct from any others which may be audible. In cases where considerable inter-

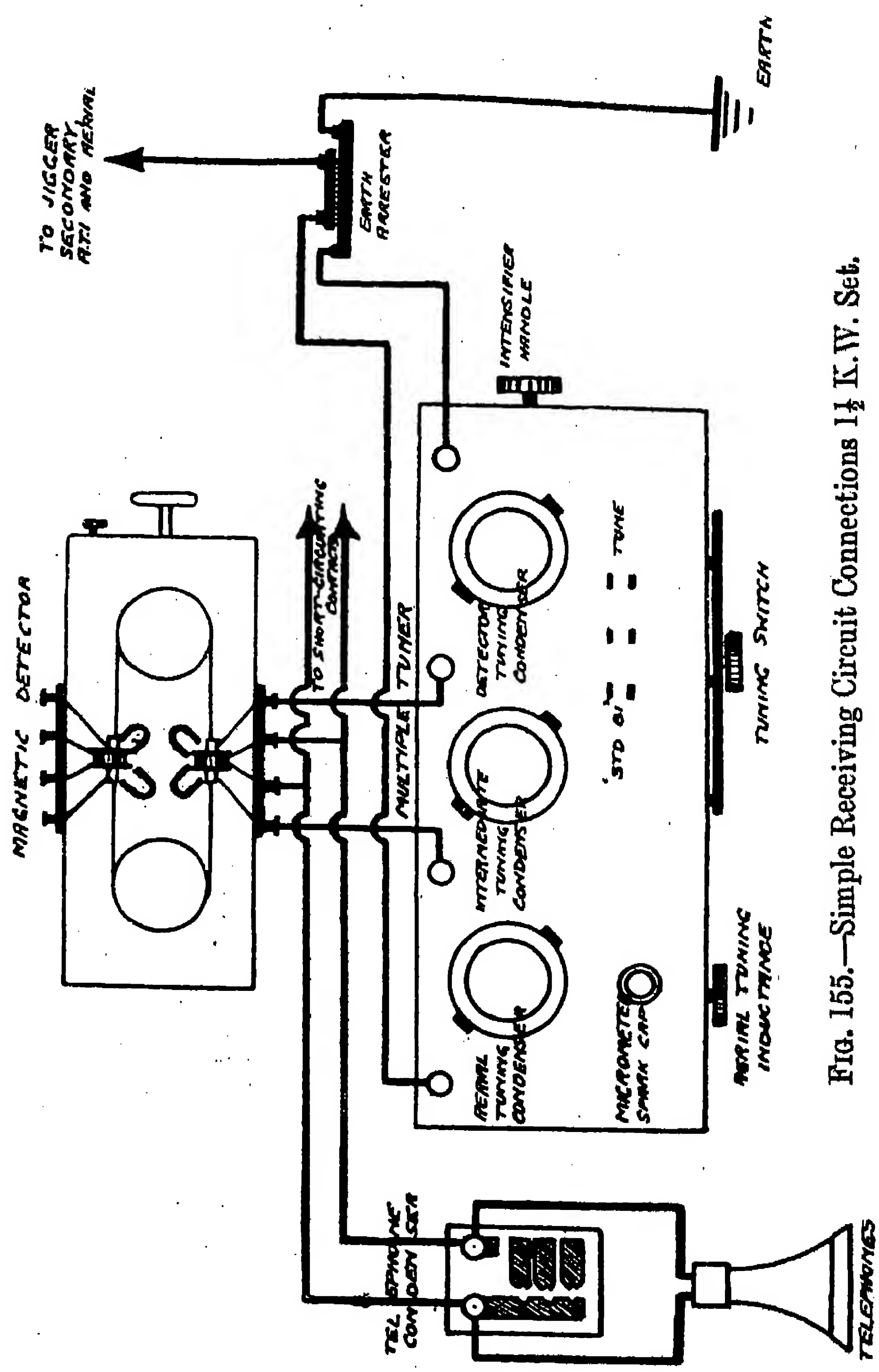


FIG. 155.—Simple Receiving Circuit Connections 1½ K.W. Set.

ference or "jamming" is met with, the aerial circuit must be tuned as nearly as possible, and the switch thrown over on to the "tune" side, care being taken that the intensifier handle is indicating an angle of 90 degrees. The tuning switch

must then be placed on the particular stop corresponding with the wave length to be received, the stop being indicated by the amount of inductance and capacity in the aerial circuit. The intermediate and detector condensers must then be varied together until the maximum strength of signals is obtained. It is very important that these two condensers should be varied together, otherwise the operator may spend a considerable time before hearing any signals at all on the tuned side. A further slight re-adjustment of the aerial tuning condenser may then be found to be necessary, and if interference is still troublesome, the coupling between the three circuits may be loosened by means of the intensifier handle. As the latter indicates an angle more nearly approaching zero, the whole apparatus is found to become more selective. That is to say, very fine adjustments become necessary, and freedom from interference is more pronounced. The diagram of the complete connections of the receiving circuit is shown in Fig. 155.

Crystal Receiver Type No. 20.—This consists of an adjustable detector circuit, and an inducing coil which is connected to the detector terminals of the multiple tuner. The multiple tuner acts as the selecting apparatus, and the crystal receiver can therefore be made very compact. The general scheme of the circuit is such as has been already described on p. 122. The receiver has two ranges, one obtained with a variable condenser alone across the jigger secondary, the other with a fixed condenser inserted in parallel with the variable condenser.

It is designed to give stronger signals than can be obtained with the magnetic detector over the principal part of the working range of the multiple tuner,—from 300 metres to 1600 metres.

Fig. 156 gives a view of the instrument. High resistance telephones of 4000 ohms per earpiece, are used instead of the low resistance phones of 70 ohms per earpiece supplied with the magnetic detector. A double-pole throw-over switch in one movement cuts off the magnetic detector from the tuner, puts on the crystal receiver, and at the same time changes over the low resistance telephones from the magnetic to a telephone transformer connected to the crystal receiver.

A diagram of the complete circuit showing magnetic

detector, tuner, crystal receiver, and accessories, is shown in Fig. 157.

NOTE.—When the crystal receiver is not in use, the potentiometer battery circuit should be broken by pulling out the pin connecting the two terminals marked "battery switch," B, Fig. 156, to prevent the dry cells contained in the receiver from running down.

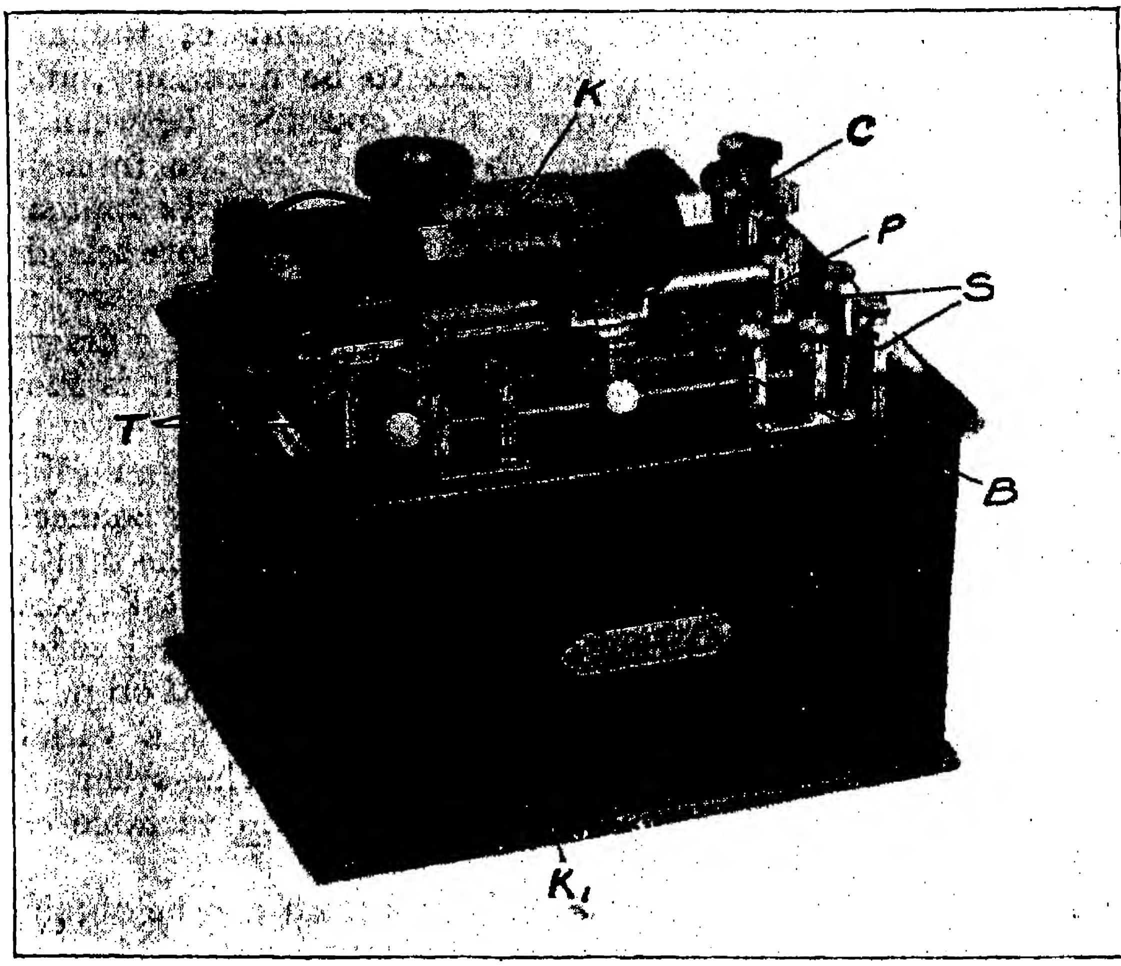


FIG. 156.—CRYSTAL RECEIVER, TYPE No. 20.

B, Pin for interrupting Battery Circuit.—C, Crystal Clip without Crystals.—K, Jigger Condenser.—K_1, Pin for Second Range Condenser.—P, Potentiometer.—S, Telephone Terminals.—T, Tuner Terminals.

Billi Condenser (*Variable*).—The maximum capacity of the variable condenser which tunes the jigger circuit of a carborundum crystal receiver, has to be kept small, in order to maintain as high as possible the H.F. potential affecting the crystal. And it follows that its minimum capacity must be very small if it is to have an appreciable range.

This instrument is therefore constructed on different lines to the ebonite disc condenser, and is known technically as a "billi" condenser. Two brass tubes—Fig. 158—slide over

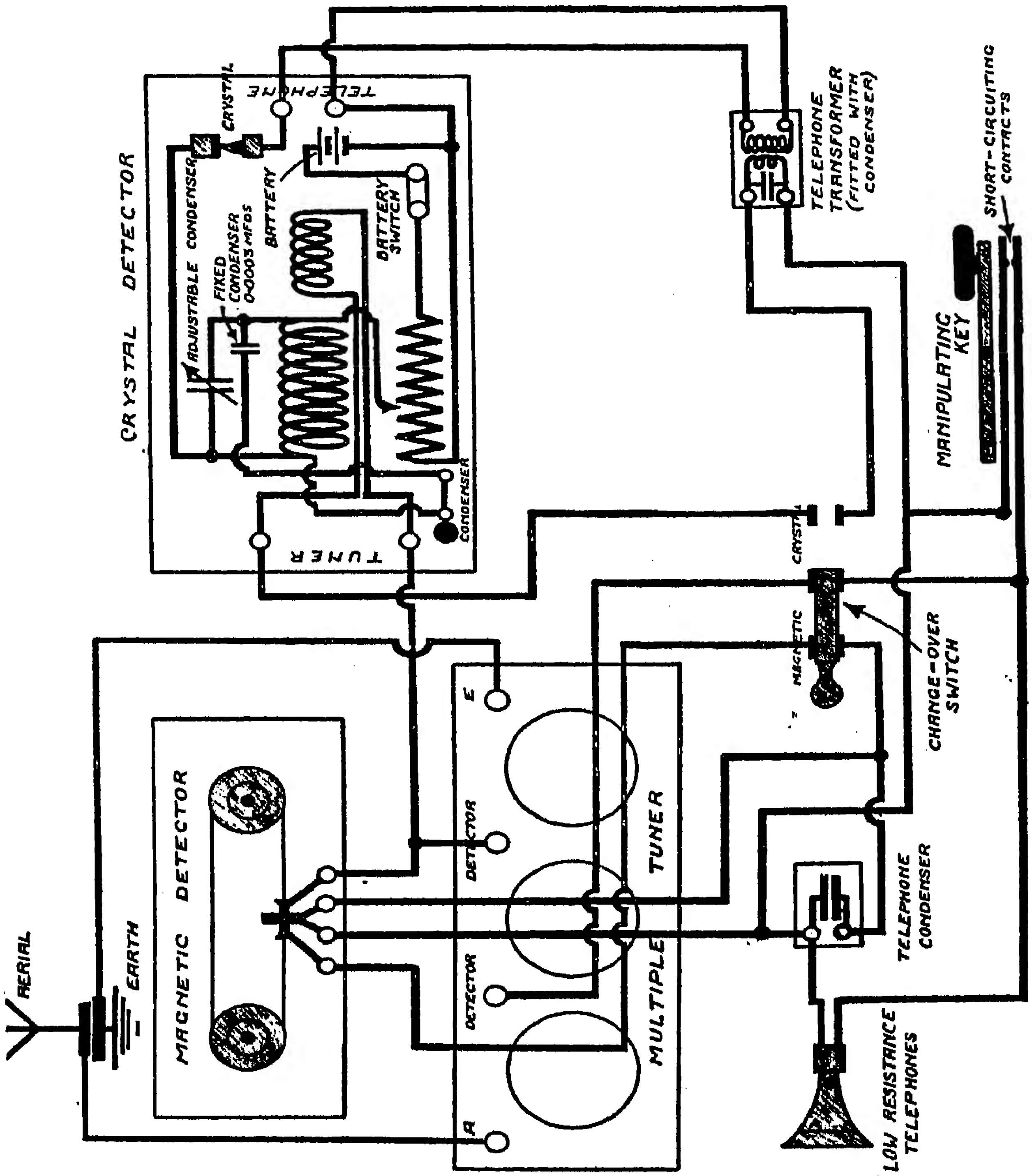


FIG. 157.—Receiving Circuit Connections 1½-K.W. Set, including Crystal Receiver, Type No. 20.

thin ebonite tubes, inside which are brass plugs. The brass tubes and plugs are the conductors, and the ebonite is the dielectric. The capacity of course depends on the area of the opposing metallic surfaces, and the thickness of the

ebonite. The active part is shaded in the diagram. For the purpose of adjusting the capacity, the tubes are given a quick movement by means of a rack and pinion fitting. One and a half turns of the milled ebonite head on the stem of the

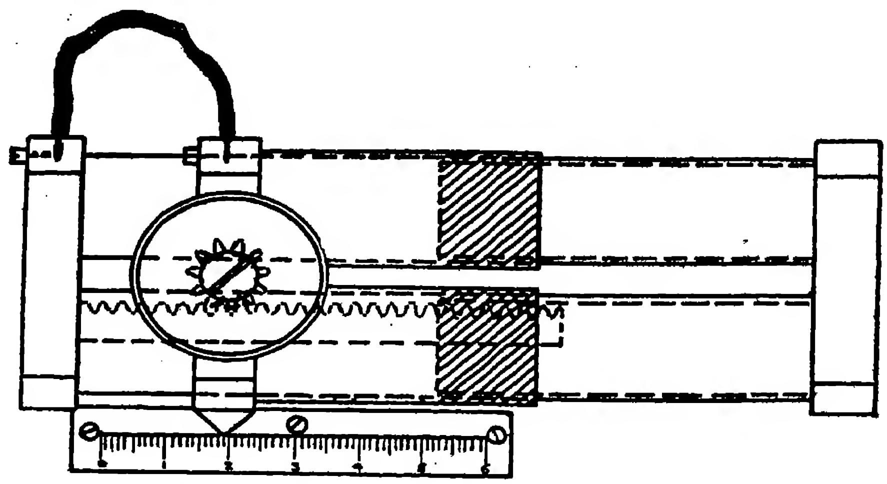


FIG. 158.—"Billi" Condenser, Rack and Pinion Type.

pinion, carries the tubes the full length of their travel—6 cms. For calibrating the instrument the tubes carry a brass index, and an ivorine scale of centimetres is fixed on the base below. The miminum capacity of such a condenser is about ·00002 mfd. and the maximum about ·00045 mfd.

Measurement of Received Waves.—The multiple tuner may be used for measuring the length of the received waves as follows :—

Tune for the received signals as already described. Then gradually decrease the coupling by turning the intensifier handle as near ten degrees as possible. *Each slight decrease of the coupling requires a slight readjustment of the variable* condensers. If the signals are still audible with the intensifier handle at ten degrees, the wave length may be read off at once from a calibration table supplied with each instrument. As the only variable part of the intermediate circuit is the condenser, it is plain that the oscillation constant and the wave length will depend directly on the value of this condenser, and the table supplied gives the wave lengths corresponding to the various values of this condenser, when used in connection with any particular stop of the tuning switch.

An example of a calibration table is given in Fig. 159. If the intensifier handle cannot be turned down to ten degrees, the reading must be taken when it is as near ten as possible ;

this, however, only giving an approximately accurate result.

Measurement of Transmitted Waves.—By connecting a loop of wire between the earth and aerial terminals of the tuner, it may be used to measure the length of the transmitted wave as follows. With the intensifier at an angle of ten degrees the tuner and magnetic detector are set up outside the cabin at some small distance from the aerial, and with the exception

TABLE OF WAVE LENGTHS CORRESPONDING TO READINGS OF INTERMEDIATE CONDENSER — WHEN INTENSIFIER HANDLE INDICATES AN ANGLE LESS THAN 10° —

WAVE LENGTH IN METRES	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT	WAVE LENGTH IN METRES.	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT	WAVE LENGTH IN METRES	TUNING SWITCH AT	INTERMEDIATE CONDENSER AT
80.			300.	150/1600	0.71	900.	150/1600	3.42
90.			325.	·	0 77	1000.	·	4 08
100.			350.	·	0.84	1100.	·	4.80
110.	80/150	0.12	375.	·	0.92	1200.	·	5.57
120.	·	0.34	400.	·	1.00	1300.	·	6.40
135.	·	0.52	450.	·	1.16	1400.	·	7.34
150.	150/1600	0.35	500.	·	1.32	1500.	·	8.35
165.	·	0.38	550.	·	1 50	1600.	1600/2000	1.32
180.	·	0.41	600.	·	1.70	1700.	·	2.76
200.	·	0.45	650.	·	1.94	1800.	·	4.05
220.	·	0.50	700.	·	2.20	2000.	·	6.80
240.	·	0.55	750.	·	2.48	2200.	2000/2600	1.06
260.	·	0.60	800.	·	2 78	2400.	·	4.40
280.	·	0.65	850.	·	3.10	2550.	·	7.04

FIG. 159.—Multiple Tuner Calibration Table.

that some aerial tuning condenser must always be used, the tuner is adjusted for reception as explained above. If the signals are inaudible with a ten-degree adjustment, the loop of wire between the earth and aerial terminals must be increased until good signals are obtained. The wave length is obtained from the calibration curve as before.

THE DOUBLE COIL SET.—Some vessels are fitted with a transmitting set similar in detail to that of the $1\frac{1}{2}$ K.W. Plain Discharger type, differing only in the fact that two 10-inch coils (see p. 206) and direct current are used instead of

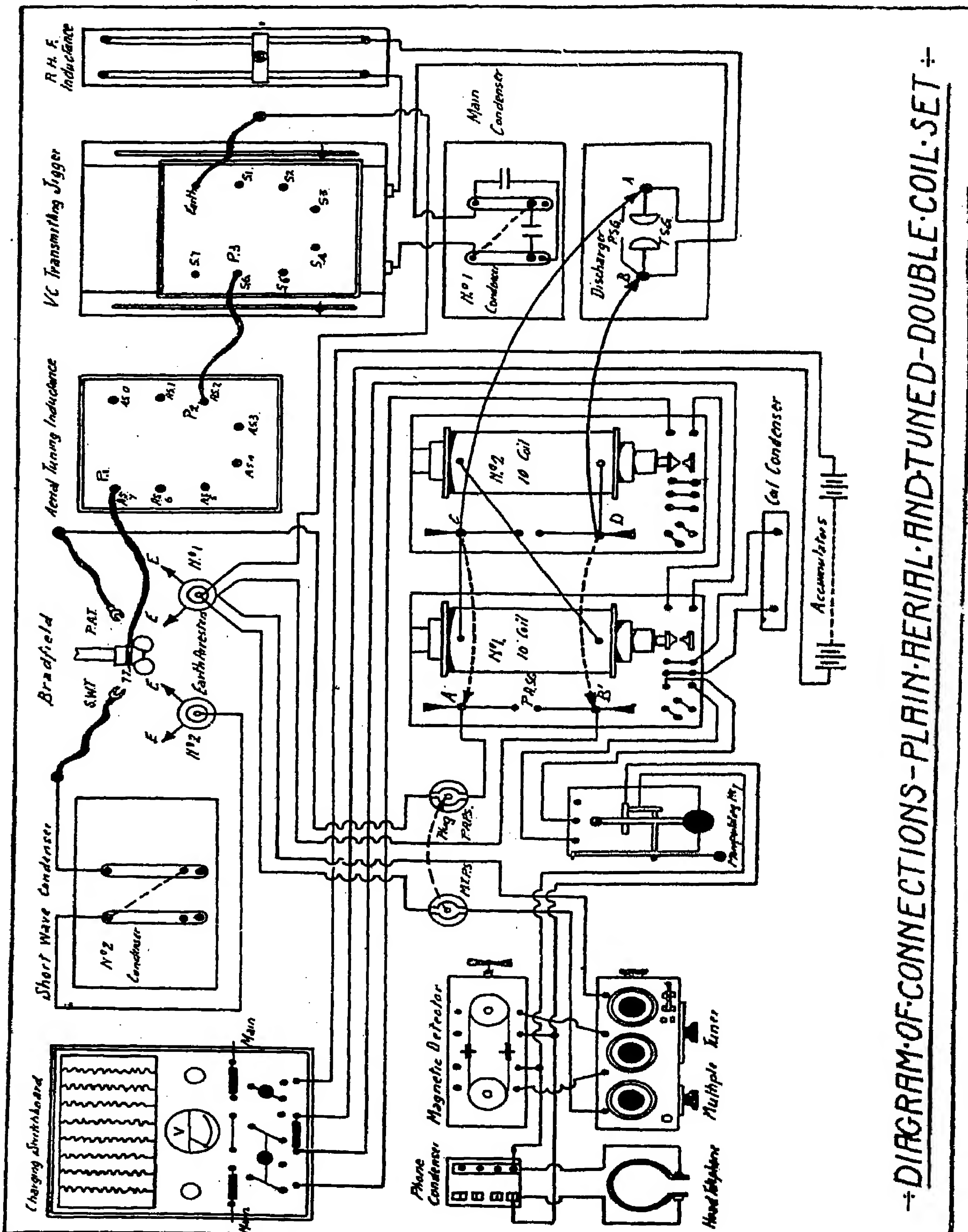


Fig. 100.—Connections of Double Coil Set.

the converter and transformer. That is to say, the closed and open oscillatory circuits are the same as in the $1\frac{1}{2}$ k.w. Plain Discharger set. In such cases the primary windings of the two coils are connected in series, and one of the breaks is screwed hard home, the condenser in this coil being disconnected. The secondaries of the coils are connected in parallel or series as in the case of the transformer, when the condenser is changed for the production of the long or short wave. The connections of such a set will be readily understood by referring to Fig. 160.

CHAPTER II.

EMERGENCY TRANSMITTING APPARATUS.

Emergency apparatus—Plain aerial coil set—Tuned coil set—Accumulator battery—Marine type switchboard No. 1—Auxiliary charging switchboard—Marine type switchboard No. 2—Induction coil—Coil emergency set connections—¼ k.w. transmitting set—Motor generator—Transformer—Transmitter.

OFFICIAL regulations controlling the use of wireless telegraphy on board ship, following the practice of the Marconi Company, now make it compulsory for an auxiliary transmitting set to be provided for use in case of breakdown of the main transmitting set, which will have a range of at least eighty nautical miles, and be capable of working continuously for at least six hours. This requirement was met in all the old installations by fitting a "Plain Aerial Coil Set" (see Fig. 161), consisting of an accumulator battery, a suitable charging switchboard, a 10″ induction coil, and a separate manipulating key. Arrangements were made whereby the coil could be quickly connected to the aerial for the production of a plain aerial spark. The advantage of this method of transmission in a case of emergency, is, that the receiving circuits of stations not strictly in tune are affected by the highly damped waves sent off. It has, however, certain disadvantages. The insulation required for the aerial and its fittings is much greater than what is required when the standard 1½ k.w. set is used, and if the operator has allowed the ebonite surface of the leading-in insulator, or the surfaces of the aerial mast-head insulators to deteriorate from the action of sunlight, salt water, and soot, without attempting from time to time to improve them by scraping, and oiling or painting with

bitumastic, it may be impossible to get a spark until the insulation is improved.

An occasional wave breaking over the wireless cabin and

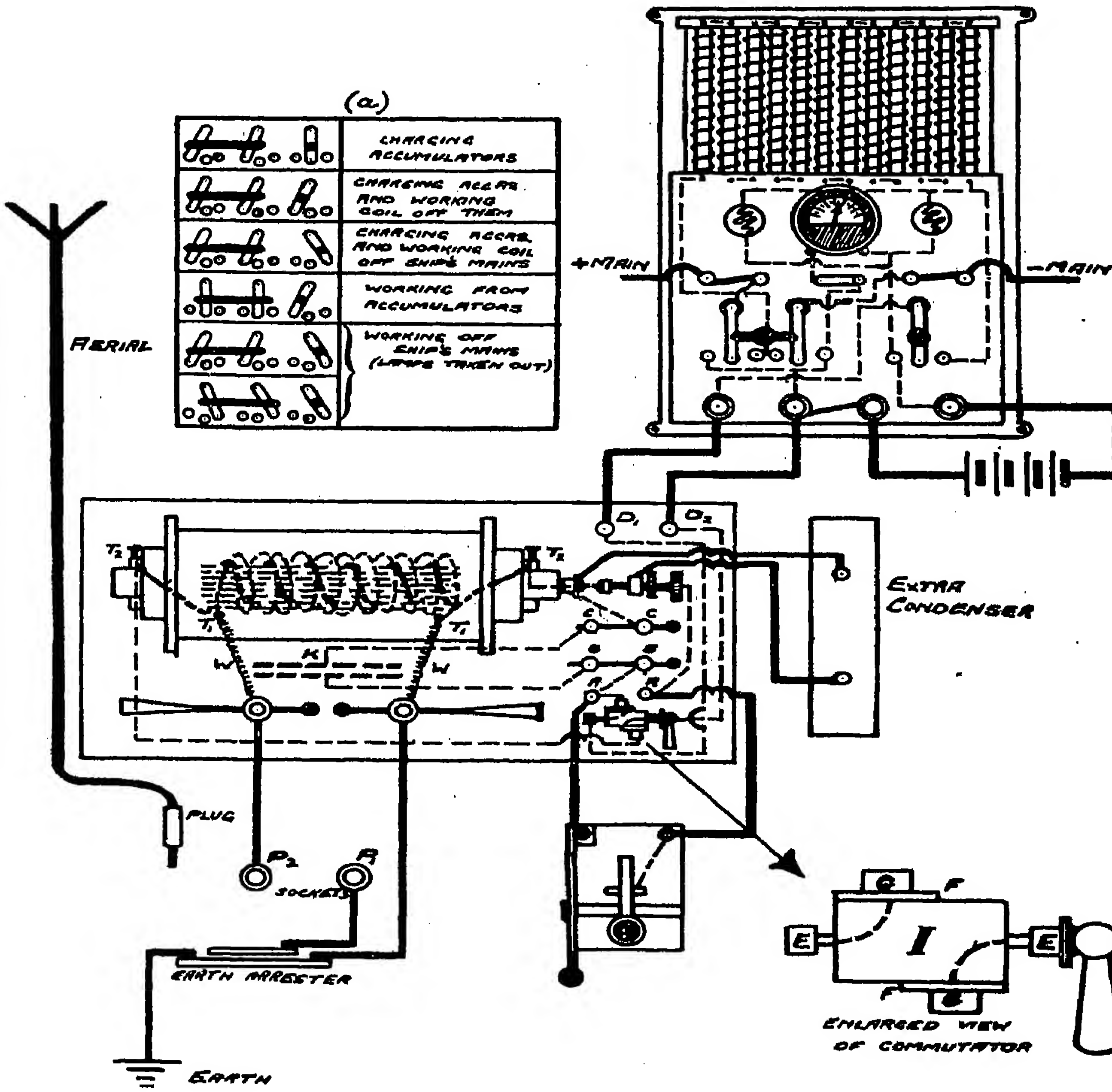


FIG. 161.—Plain Aerial Emergency Transmitting Gear Connections.

leading-in insulator, if the rain cone is not effective, would cause a similar breakdown.

An alternative arrangement, known as a "Tuned Coil Set," is therefore used in many cases.

The battery, charging board, 10″ induction coil, and manipulating key are required as before, but now the 10″ coil replaces only the converter and transformer, it does not

directly charge the aerial. It is connected through the protector chokes to the condenser of the standard $1\frac{1}{2}$ k.w. set, the jigger and plain discharger being also in circuit.

The installation will now transmit on its normal wave-lengths, but with a reduced spark-length corresponding to the diminished power available. This arrangement does not require a high degree of aerial insulation.

If the main installation is a $1\frac{1}{2}$ k.w. disc set (see Fig. 162) the disc will be stationary, and the spark will have to pass from the electrodes to the stationary disc studs. In order to equalise the wear on the studs the disc will have to be moved

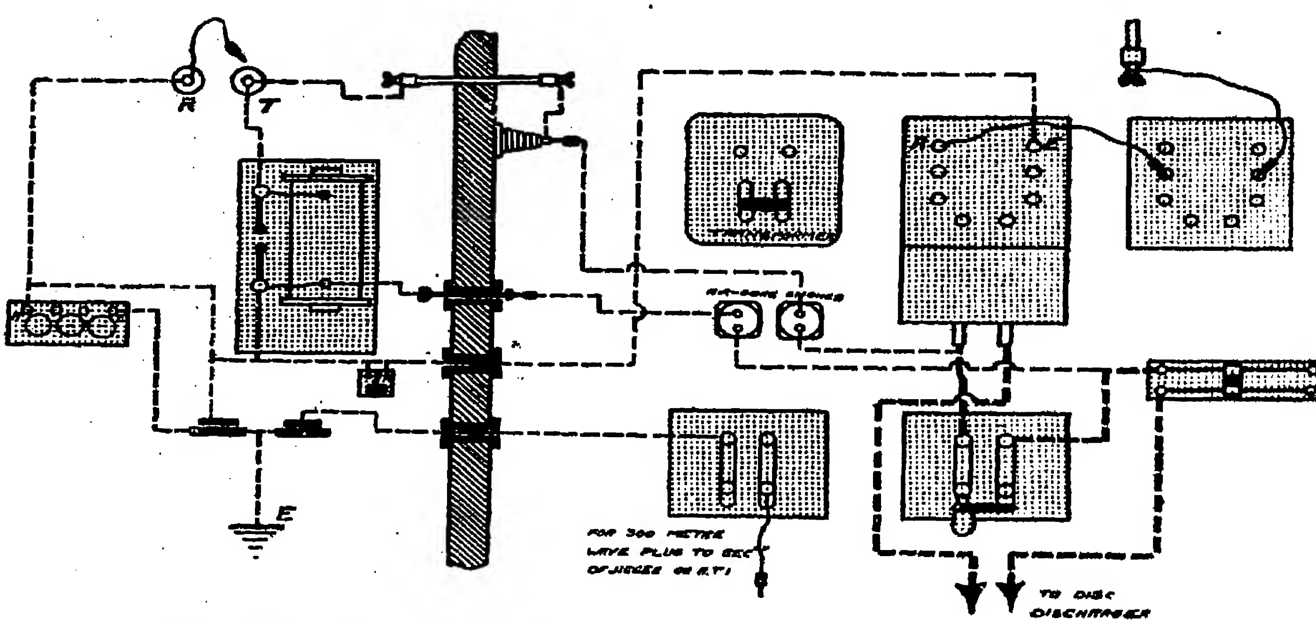


FIG. 162.—Tuned Coil Emergency Transmitting Connections.

round occasionally. Fig. 163 gives a view of a complete $1\frac{1}{2}$ k.w. set, as it would be erected on board ship. The tuned transmitting gear is contained in a silence cabin in the wireless room, and the receiving and coil emergency gear is fitted on an operating bench alongside the silence cabin. The special parts of the two emergency sets mentioned above will now be described.

The Accumulator Battery, and Marine Type Switchboard.—The accumulator battery consists of eight "Chloride" secondary cells. It is used to supply current to a ten-inch induction coil, which has a primary winding of a resistance of about ·19 ohm. The ordinary working current taken by this coil is about eight ampères at sixteen volts, hence the necessity of using eight cells in order to obtain the necessary E.M.F.

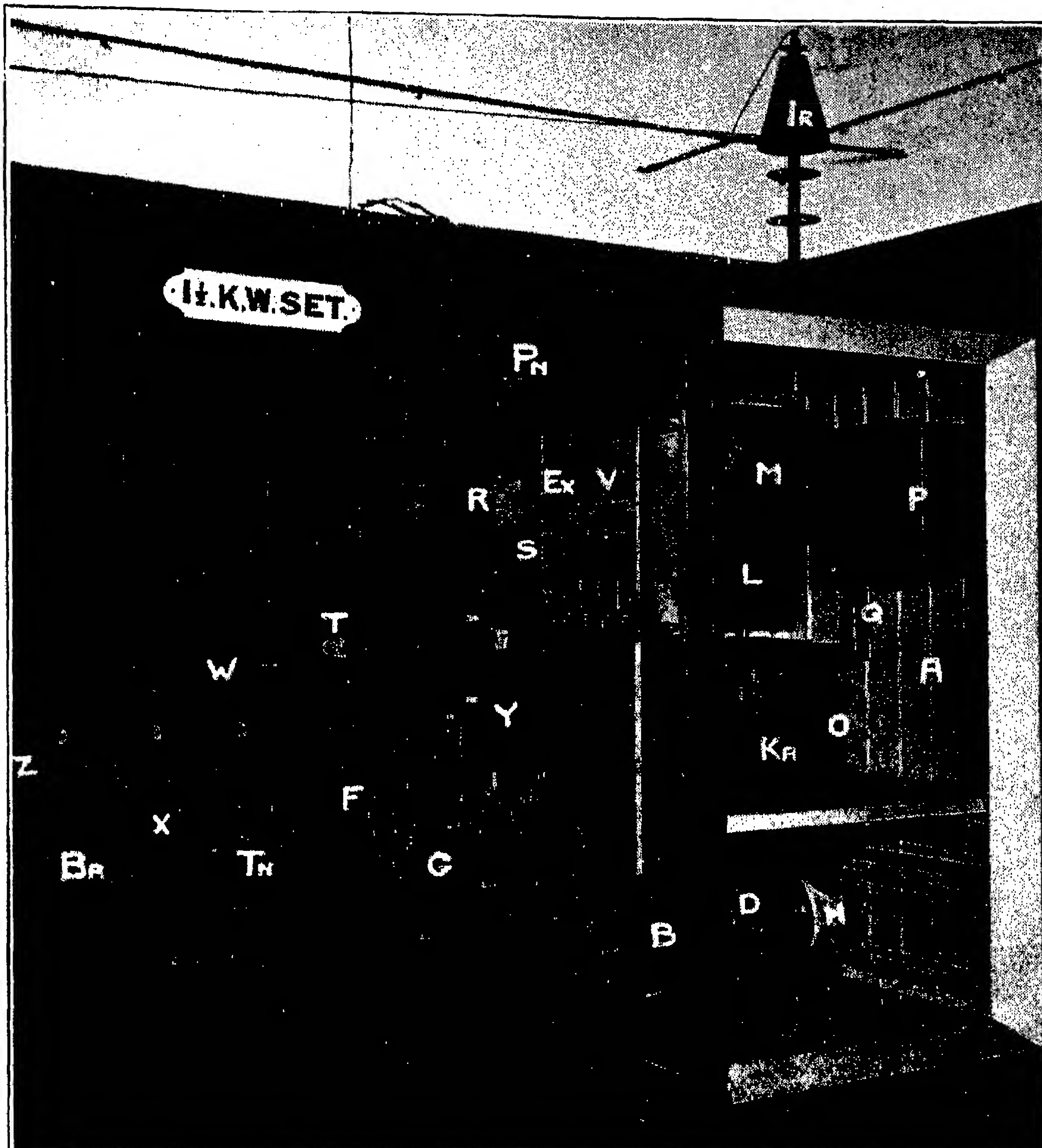


FIG. 163.—1½ K.W. SET INSTALLED AT MARCONI HOUSE.

A, Main Switch.—B, Starter.—D, Rotary Converter.—F, Magnetic Key.—G. Manipulating Key.—L, Jigger Primary.—M, Jigger Secondary.—N, Discharger.—O, Transmitting Condensers.—P, Aerial Tuning Inductance.—Q, High Frequency Sliding Inductance.—R, Tuning Lamp.—S, Earth Arrester Spark Gaps.—T, Plain Aerial Plug Socket.—V, Marine type Charging Switchboard.—W, Magnetic Detector.—X, Multiple Tuner.—Y, 10″ Induction Coil.—Z, Telephone Condenser.—BR, Buzzer.—EX, Extra Charging Resistance.—IR, Bradfield Leading-in Insulator.—KA, Short Wave Aerial Tuning Condenser.—PN, Partition Insulator.—TN, Telephones.

[*To face p.* 200.

Each cell contains five negative and four positive plates, the respective groups appearing as shown in Fig. 164 (*a*) and (*b*). The cells are connected to a switchboard (Fig. 165) fitted with a resistance and carbon filament lamps, by means of which the voltage of the ship's supply is reduced to that required for charging. This switchboard is also supplied with a single-pole three-way, and a double-pole three-way switch. The former is used to connect up the coil to the circuit, and the latter to connect up the accumulators to the charging dynamo.

In the general notes on accumulators it is stated, that great care must be taken to connect the positive pole of the battery

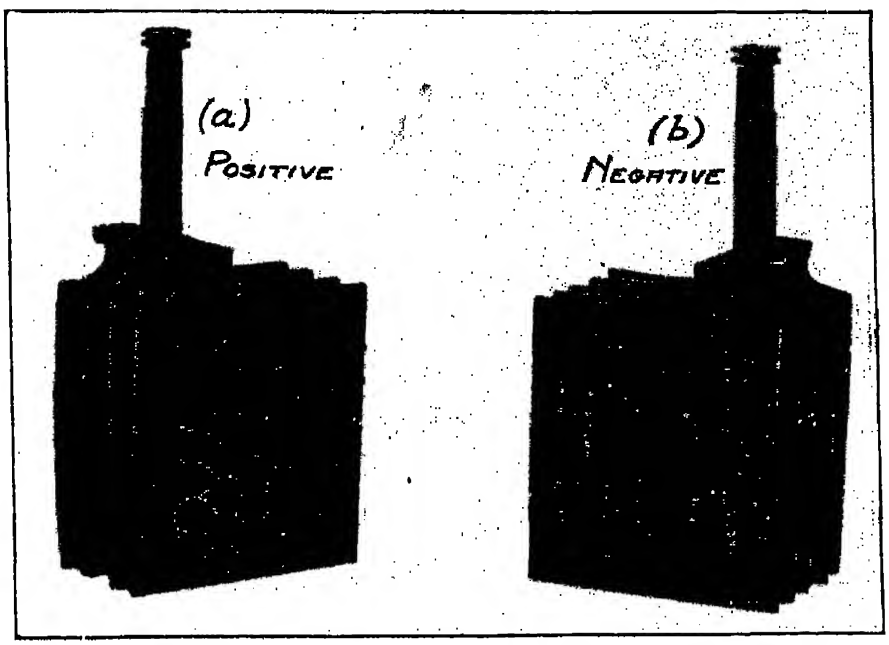


FIG. 164.—Accumulator Plates.

to the positive pole of the dynamo when charging. The above-mentioned lamps afford a simple means of recognising when such connections have actually been effected. If the double-pole switch be placed in turn in each of its two possible positions, it is seen that the lamps glow with two different degrees of intensity. The position of the switch at which the lamps glow *least* brightly, is the correct position for charging. The position of the double-pole switch determines the direction of the charging current through the battery.

On ships carrying more than one dynamo, it sometimes happens that the mains are so connected that different polarity is given by one machine than is given by another. The use of

the double-pole switch is now apparent. It obviates any necessity to alter the switchboard connections of the battery, as a mere changing over from one position to the other produces a compensating reversal of the charging current. At the same time, it is evident that an operator should never leave a battery on charge when away from the room where such a

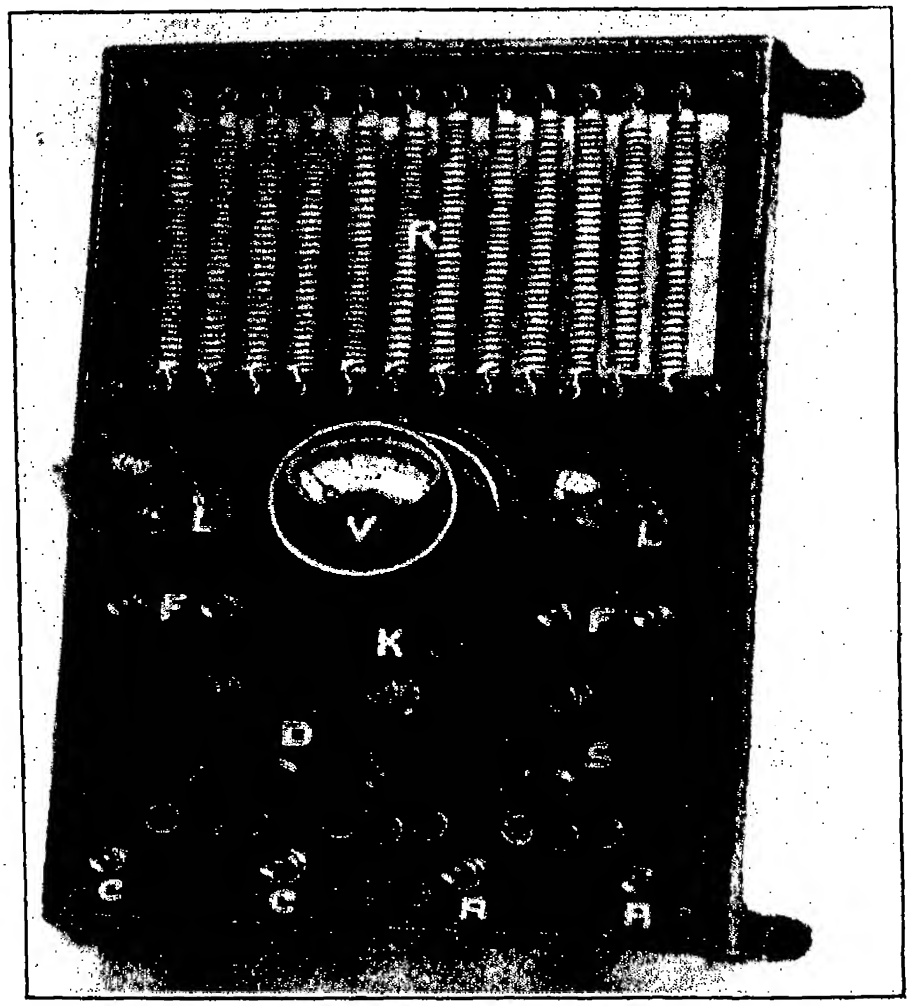


FIG. 165.—MARINE TYPE SWITCHBOARD, NO. 1.

A, Accumulator Battery Terminals.—C, Coil Circuit Terminals.—D, Double-pole Switch.—F, Fuse Terminals.—K, Voltmeter Key.—L, 50 c.p. Lamps. —R, Charging Resistance.—S, Single-pole Switch.—V, Voltmeter.

change of polarity is possible. This switch is also useful in another way. When overhauling the accumulators, the connections to the switchboard may have been removed. If, when connecting the accumulators up again, the operator should accidentally reverse the connections, the glow of the lamps shows him in which position to leave the switch in order

to rectify the change. The accumulator battery is not very largely used, and the arrangement of the charging resistance is such as to only allow of its being charged very slowly. The resistance has a value of four ohms, and the two fifty candle-power carbon filament lamps, which are in parallel with each other and in series with the rest of the charging circuit, allow a charging current of about four ampères to pass. The normal charging rate of the battery as given by the makers is 12 ampères, so it will be seen that in order to keep it well charged up long charges must be given.

As there are eight cells, the voltmeter with which the switchboard is supplied should give a reading of eight times 2·6 volts, that is 20·8 volts when the battery is fully charged with the charging current still passing. The specific gravity of the acid at this stage should be 1·215, and gas should be freely bubbling from both positive and negative plates. A little time after the charging current has been cut off, the reading of the voltmeter should be about 17 volts, or approximately 2·1 volts for each cell. As the voltage of a cell should never be allowed to fall below 1·85, the total voltage as shown on the voltmeter should never fall below 14·5, and 15 is a much safer limit. The specific gravity of the acid should then be about 1·170.

If it is necessary to remove the plates from a cell in order to inspect them, great care must be taken when replacing them to see that the pole pieces agree with the marks on the outside of the container. Care must also be exercised when replacing the covers, that the positive and negative signs are adjacent to the corresponding poles. When disconnecting one cell from another, care must be taken not to allow the flexible connections to short-circuit any cell. The switchboard connections are shown theoretically in Fig. 166, and actually in Fig. 161.

If it is impossible to obtain distilled water to replace that lost by evaporation, rain-water or the cleanest water obtainable must be used, and care must be taken to see that it is free from sediment. Acid must on no account be added to make up a deficiency of water. In order to keep the battery in an efficient condition it is advisable to work from it at least for a short time each day.

A great deal of the disintegration of the plates so often found in the accumulators, is due to operators allowing the

battery to remain on charge from one end of a voyage to the other.

The lamps on the switchboard are not intended for lighting or heating purposes, and consequently when the battery is fully charged the current should be cut off, as continued excessive overcharging merely causes furious bubbling, which, as has been previously explained, results in disintegration of the plates.

The capacity of the battery is 80 ampère hours, by which is meant that a current of eight ampères may be taken from it for a period of 10 hours. If a heavier current be used, the

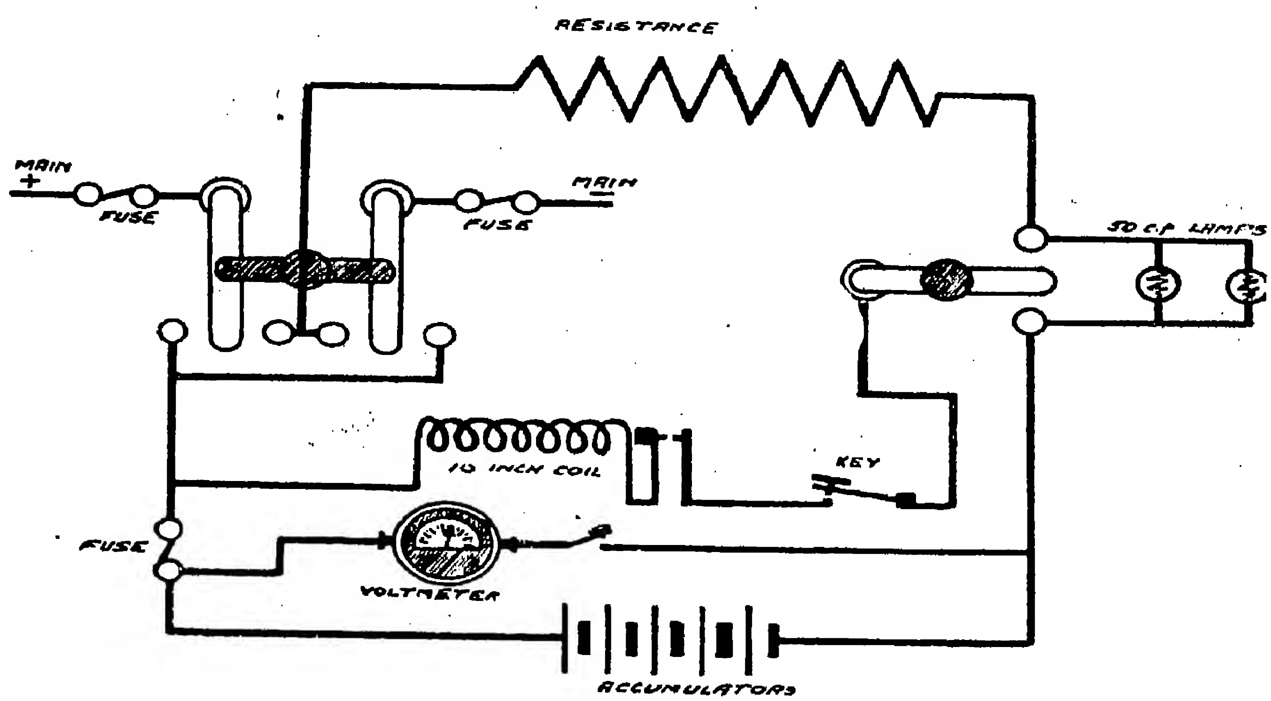


FIG. 166.—Emergency Transmitting Gear, Primary Circuit (Theoretical).

capacity in ampère hours is a little less, and if a smaller current be used it is a little more.

The normal charging current of 12 ampères, takes about $7\frac{1}{2}$ hours to charge fully a battery which has been run down to its safety limit. This we see gives ninety ampère hours, so that the efficiency of the battery is represented by the ratio of 8 to 9, or, in other words, the battery is said to have an 88·8 per cent. efficiency. Several combinations of the two switches on the switchboard may be used for different purposes. Thus it is possible either to charge the battery alone, to charge the battery and work the coil from the main current, to work the coil from the battery current, or to work the coil from the main

current. The different arrangements of the two switches are shown in Fig. 161 (*a*).

This switchboard was originally designed for working off ships' mains at a pressure of 60 to 80 volts, also the accumulators had either to be taken on board fully charged, or they had to be connected to the coil terminals for a first charge if a large current was required from the ship's mains, or else their first charge had to be made at the low rate of four ampères allowed by the lamp resistance. In order that this board could be used on a more extended range of voltage,

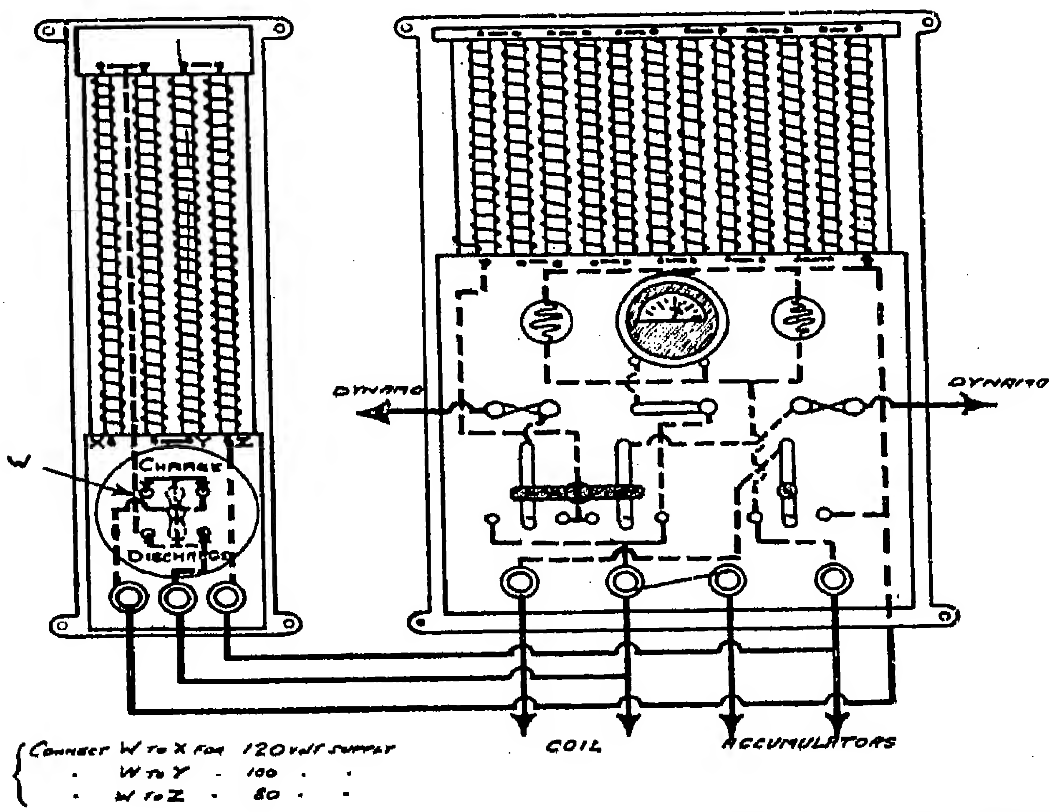


FIG. 167.—Auxiliary Switchboard connected to Marine Type Switchboard No. 1.

and that the battery could be able at any time to take a heavy charge from the mains by means of a simple switch-over connection, an auxiliary switchboard has been supplied in many cases, the connections with the main board being shown in Fig. 167.

The latest type of board is illustrated in Fig. 168. This has a double-banked row of resistance rods—shown one row above the other in the diagram—having suitable tapping connections so that it can be used on any supply from 60 to 120 volts, the double-pole throw-over switches making it

possible to work the induction coil off either the ship's mains or accumulators, and the accumulators can be connected either

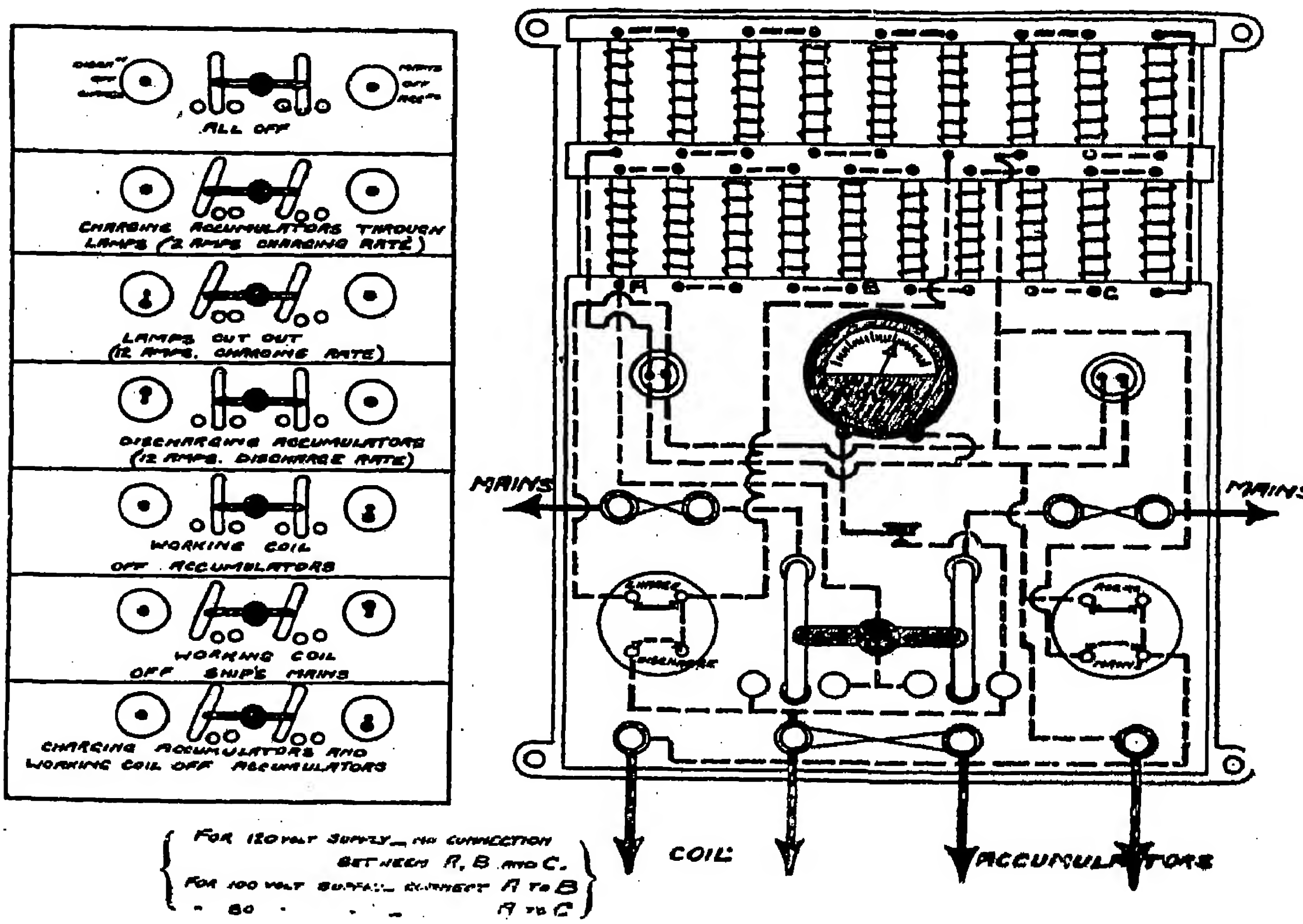


Fig. 168.—Marine Type Switchboard No. 2.

for maximum charge, normal charge, or discharge, by one movement of a switch.

E.P.S. Accumulators.—The E.P.S. type of accumulator is also sometimes installed with standard sets of Marconi apparatus. The general instructions given with respect to the "Chloride" type may be followed. The normal charging rate for the E.P.S. cells used is 10 ampères, instead of 12 as used for the "Chloride" accumulator. Of course, a battery is never composed of a mixture of both types.

The Induction Coil.—Fig. 161 shows the connections of the 10-inch induction coil, which is also illustrated in Fig. 169. A primary winding of 360 turns of No. 12 D.C.C. copper wire, is wound over a core of stranded soft iron wire. The ends of this winding are brought through the ebonite ends of the casing in which the coils are contained, and are supplied with small brass thimbles by means of which connection may be made to two

terminals, T_2, mounted on the ebonite supporting blocks. This arrangement facilitates packing for transport, etc., as the coil may be easily removed from its base and separately packed. The core and primary winding are contained inside an ebonite tube, over which a secondary coil of 54,000 turns

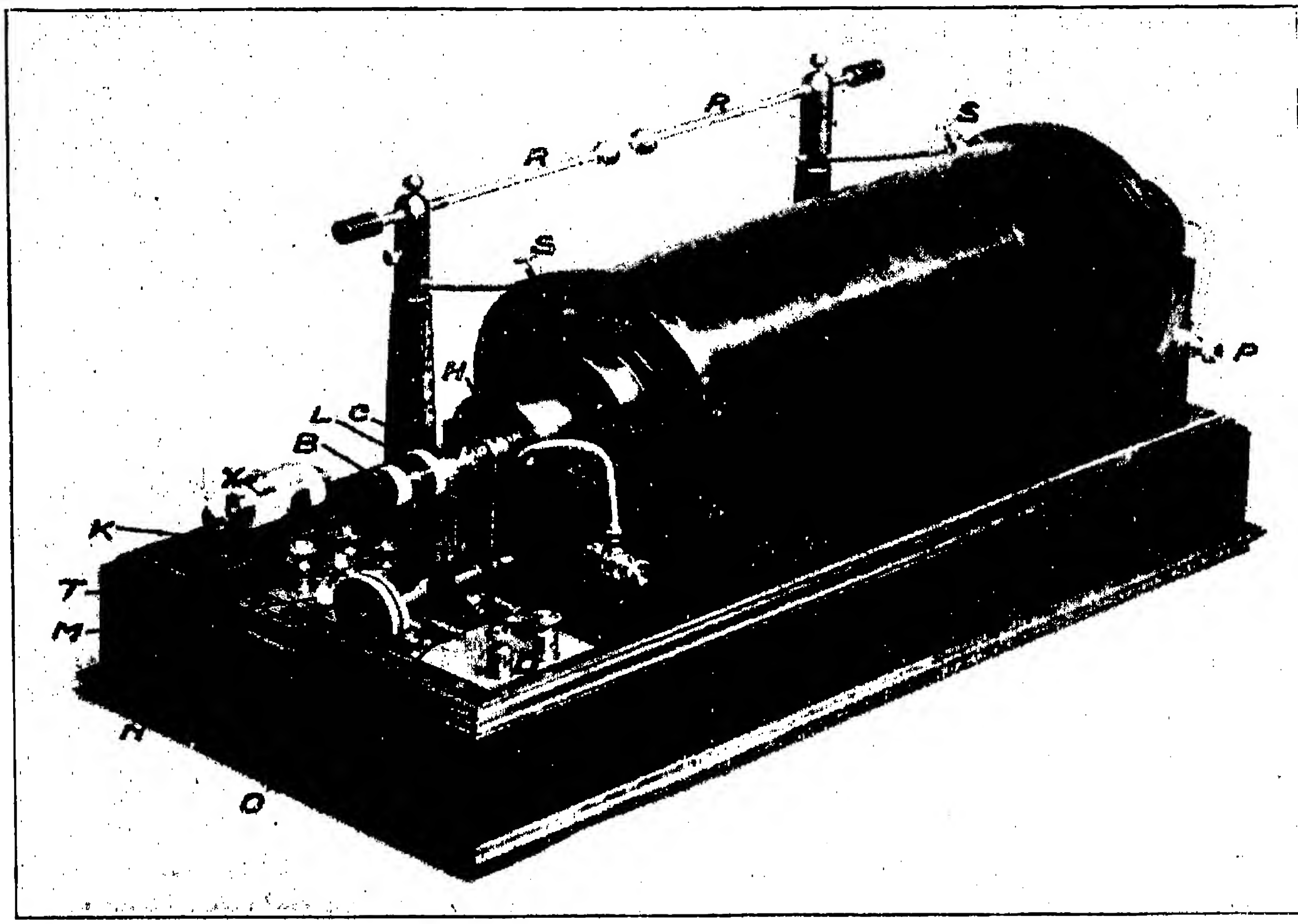


FIG. 169.—10″ INDUCTION COIL.

B, Back Contact Adjusting Screw.—C, Platinum Contacts.—D, Main Terminals.—H, Hammer.—K, Manipulating Key Terminals.—L, Lock Nut for Break Adjustment.—M, Condenser Connecting Pin.—N, Tension Adjusting Screw.—O, Terminals for Extra Condenser.—P, Primary Winding Terminals.—R, Discharge Rods.—S, Secondary Winding Terminals.—T, Condenser Terminals.—X, Commutator.

of No. 34 silk-covered copper wire is wound. This secondary coil is wound in 116 sections, each section being contained in a former of insulating paper; one reason for this being that any breakdown can be more easily located and repaired. A more important advantage gained by this method of winding the secondary, is, that a high potential difference does not

exist between any two adjacent turns, and therefore there is less risk of a breakdown of the insulation. The sections are connected in series, the two extreme ends being connected to two terminals, T_1, mounted on the ebonite cylinder which encloses the coils. Brass discharge rods, each fitted with a small ebonite handle at one end and with a brass sphere at the other, are mounted on two ebonite supporting pillars, and are connected to the terminals T_1, through choking coils of fine insulated wire, W. A hammer break is employed, the construction of which is seen in Fig. 170. A vertical brass spring, S, carrying a soft-iron hammer, H, at its upper extremity, is fitted with a platinum contact, C. A second platinum contact C_1, is mounted at the upper end of a brass supporting pillar, P, its position with respect to the first contact being adjustable by means of the screw, M, and lock nut, N. The tension on the spring, S, is adjusted by means of the screw K—supplied with an ebonite handle, E—which passes through an insulating bush, B, fixed in the brass supporting pillar, P. When using this break, care must be taken that the faces of the contacts are in parallel relationship and thoroughly clean. They must be cleaned occasionally with a smooth file. The play of the hammer between the end of the core and the back contact is regulated by means of the screw M, and, with a proper adjustment, the hammer will give twenty-five interruptions per second.

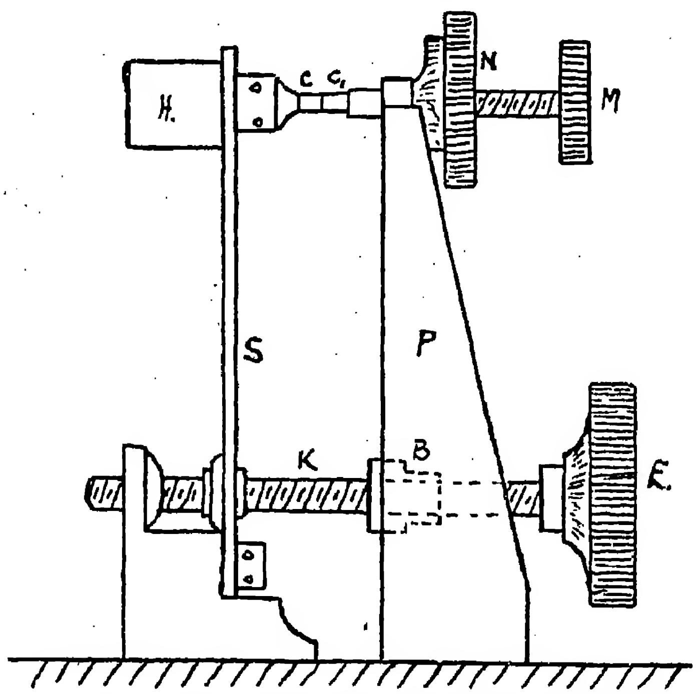


FIG. 170.—Hammer Break for Induction Coil.

Two terminals, D_1 and D_2, are connected externally to the source of current supply, and internally to the brass supporting pillars of the commutator. The commutator provides a means of altering the direction of the current through the primary winding. An ivory drum, I, is mounted on two brass supporting pillars, E, each pillar being connected internally

to one of two brass contact pieces, which are placed on opposite sides of the drum. A small ivory handle is fixed at the right-hand end of the drum, by means of which the latter can be turned on the axis, EE. When this handle is in a horizontal position, as shown, the brass contact pieces, FF, are pressed hard against two vertical brass springs, GG. If the handle be turned through 180 degrees, the positions of F and F are reversed, and by tracing out the circuits it is seen that the direction of the primary current is different for each position. When the handle is in a vertical position the circuit is broken, as there is no longer any contact between the vertical springs and the brass contact pieces. In front of the hammer-break six terminals are mounted in pairs. The two nearest the commutator, marked AA, are connected to the manipulating key, whilst the other two pairs, marked BB and CC, are fitted with two copper pins. The inside terminals B and C, are connected internally to a condenser, K.

The Coil Condenser.—This condenser, which has a capacity of approximately 2 microfarads, consists of alternate layers of

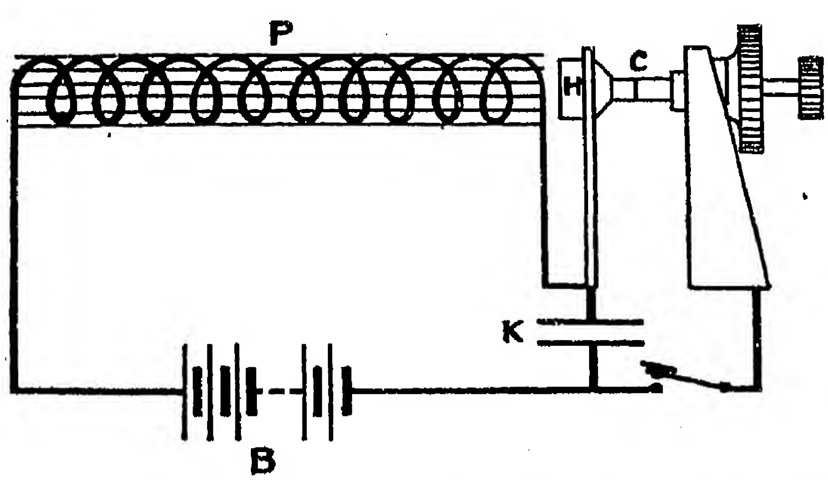


FIG. 171.—Primary Circuit of Induction Coil (Theoretical Sketch).

tin-foil and varnished paper. Alternate sheets of foil are connected at one end, the remaining sheets being all connected at the other end. Because the dielectric varnished paper is very thin, and the area of the conductors comparatively large, a fairly large capacity is contained in little space. In all there are 140 sheets of foil in the condenser. Fig. 171 shows the coil and condenser connections in a simple manner. When the key is depressed, a current flows from the battery, B, through the primary winding, P, and the contacts, C, back

through the key to the battery. The core of the coil is magnetised, and the hammer, H, is attracted. The circuit is thus suddenly broken at C. It has already been explained that any variation of the current in a circuit, varies the number of linkages of lines of force, and induces an E.M.F. tending to oppose the change of current. We see, therefore, that this breaking of the primary circuit produces a self-induced E.M.F. having a tendency to continue the current across the contacts.

This E.M.F. is of so high a value, that a vivid spark takes place between the gradually-opening contacts, unless steps are taken to prevent it. This spark, or the metallic vapour in the spark, renders the air between the two contacts conductive, and the result is that the primary current continues to flow until the gap at the break is too large for

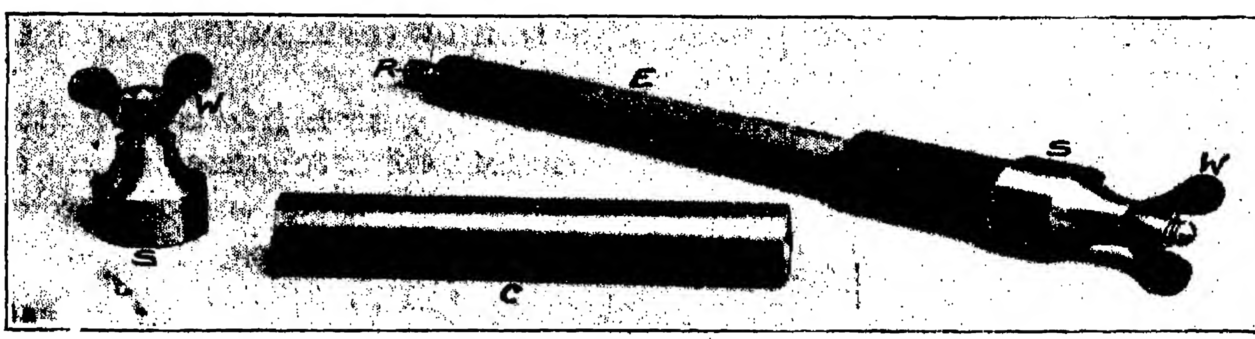


FIG. 172.—PARTITION INSULATOR.

C, Ebonite Sleeve.—E, Ebonite Tube.—R, Steel Rod.—S, Brass Terminal Socket.—W, Brass Wing Nut.

the induced voltage to bridge. If the primary current is thus slowly cut off the induced effect in the secondary is only slight, as the rate of cutting of lines of force is slow. The importance of the condenser K is now evident. Immediately the contacts begin to separate, the induced E.M.F., instead of sparking across, is taken up to charge the condenser, the primary current being thus interrupted extremely quickly. Two beneficial results ensue. The spark being eliminated, no burning away of the platinum contacts takes place; and because the primary circuit is broken very quickly a much greater E.M.F. is set up in the secondary. It will be seen, moreover, that the charged condenser K is still in a closed circuit through the battery B and the primary winding, but that its E.M.F. is in the opposite direction to that of the battery. It begins to discharge itself through this circuit, this also tending to increase the effect in the secondary. When the primary

circuit is broken, the core loses its magnetism and the hammer is released, contact being once more effected at C. If contact is made before the condenser is discharged, the primary current has first to overcome this back E.M.F., and as a consequence the rise of current—obstructed at the same time by the self-induction of the primary winding—is comparatively slow, and the induced E.M.F. in the secondary is of a correspondingly low value.

To summarise, the condenser helps to eliminate sparking at the contacts, helps to accelerate the "break" of the primary circuit, and helps to retard the current at the "make."

The result is that a much greater induced E.M.F. is produced at break than at make, and as a matter of fact if the spark gap in the secondary circuit be fairly large, an intermittent unidirectional spark takes place. It will be seen that the condenser in the circuit shown also helps to eliminate sparking at the manipulating key contacts. It is often found in practice that the coil works better with an extra condenser across the break, and terminals are mounted on the hammer spring base, and on the back contact supporting pillar, for making connection to an extra condenser, which is of the same type and dimensions as that contained in the base of the coil.

By means of the copper pins, the coil base condenser may be easily cut out of circuit in the event of its breaking down.

Connections of Plain Aerial Emergency Set.—Fig. 161 shows the complete connections between the various parts of the Plain Aerial emergency set. P_1 and P_2 are two wooden pillars, each fitted with a brass plug socket. P_1 is permanently connected to the top plate of the earth arrester, and P_2 to one of the coil discharge rods. The other coil discharge rod is connected to the bottom plate of the arrester. A piece of 20 ampère flexible cable, fitted with a boxwood and brass plug at one end, and a brass thimble at the other, is used to make connection between the lower end of the aerial and either of these plug sockets. For transmitting, the plug is placed in socket P_2, when it is seen that the aerial is connected to one discharge rod, the other rod being connected to earth. The choke-coils between the discharge rods and the ends of the coil secondary winding, when large enough, tend to prevent any oscillatory currents from the aerial-earth system rushing into the coil and damaging it. When the plug is placed in socket P_1, the aerial is

disconnected from the coil and connected to the receiving circuit joined across the earth arrester. If the coil were not disconnected from the aerial, a direct path to earth for the received currents would exist through the secondary winding, not so much by way of the wire of the winding (which has too great an inductance to afford a path to signals of ordinary wave-length) as by a capacity effect from layer to layer, and section to section, to the earth-connected end.

When using the coil emergency set, the connection from the aerial tuning inductance to the lower end of the aerial is, of course, removed, and replaced by the flexible connection mentioned above.

The ¼ K.W. Transmitting Set.—A special form of emergency gear has been recently developed which has several useful features. It is designed to run off a battery of 30 cells, each of 80 ampère-hour capacity. It has an A.C. output on spark of 250 watts. It has an effective range on a normal ship's aerial of 150 nautical miles. It is capable of transmitting continuously for some ten hours. It gives a musical note of 600 per second.

Its jigger and condenser are combined in one piece of apparatus called the "transmitter," which is readily portable. The following is a description of its principal parts :—

The ¼ K.W. Motor Generator.—A view of the machine is given in Fig. 173. It provides an alternating current supply of 250 watts at 110 volts 300 cycles. The carcase carries two windings, (1) the field winding of the four-pole motor ; (2) the stator armature winding of the alternator.

The motor armature, and the alternator twelve-pole rotor field, are on the same shaft, but they are quite separate from each other. An extension of the shaft at the alternator end carries the disc of a rotary discharger. The spark is synchronous, that is, it is in step with the alternator frequency, and the number of disc studs is therefore twelve, agreeing with the number of alternator field poles. The disc box of aluminium, carries the two ebonite bushed electrode terminals. The box can be moved round when it is necessary to alter the phase position in the half cycle at which the spark occurs. The theory of the synchronous spark discharge is given on pages 253 and 254. By turning the brass terminal heads, the copper electrode rods are fed down towards the disc studs, and by this means any shortening due to burning

can be compensated for. The electrodes can be fed down one inch before it is necessary to renew them. Another type of disc is sometimes used, in which the studs are transverse and the electrodes are mounted on an ebonite end plate, capable of rotation for spark phase adjustment. This type may finally become standard.

An enclosed combined starter and motor field regulator with no-volt release is supplied with the machine. The starting resistance is removed by one movement of the handle, not in steps. In fact the motor could be started up without

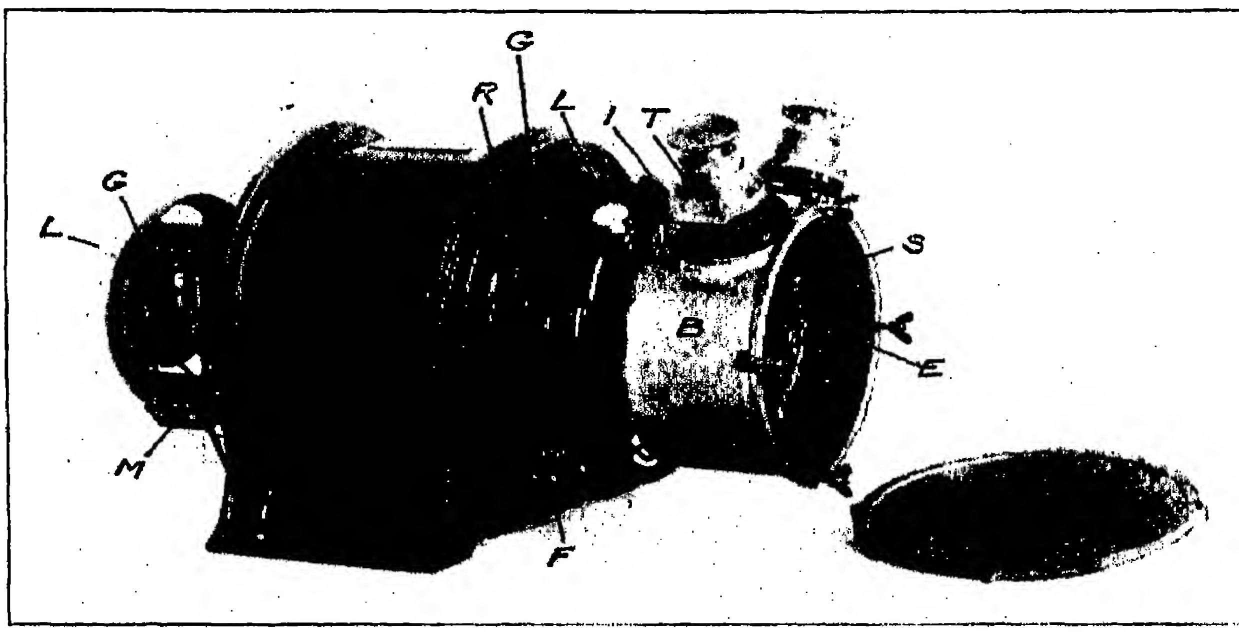


FIG. 173.—THE ½ K.W. MOTOR GENERATOR.

B, Aluminium Disc Box.—C, Disc Box Cover.—E, Ebonite Disc.—F, Motor Field Terminal Sockets.—G, Brush Gear.—I, Index.—L, Stauffer Lubricator.—M, Motor Armature Terminal Sockets.—R, Slip Rings.—S, Disc Studs.—T, Electrode Terminal Plate.

excessive sparking at the brushes, using no starting resistance at all. However, the resistance supplied certainly helps to keep the commutator clean, and therefore lessens the amount of attention which has to be paid to it, which is of importance in emergency gear.

The motor field winding has been carefully adjusted so that the machine runs at 3000 r.p.m. on the constant voltage supply of the battery, and on full load, and maintains this speed with very small variation when warmed up. A motor field regulator then is hardly required; the regulating resistance supplied is mainly for the purpose of keeping up the

converter speed when the battery voltage commences to drop. In the same way the windings of the alternator have been carefully worked out so that the output on spark with the standard transmitter is 250 watts, without any final adjustment of A.C. voltage by means of an alternator field regulator being necessary. The alternator field connections are therefore permanently made direct to the motor brushes.

The ½ K.W. Switchboard.—This board is similar in appearance to Marine Switchboard No. 2, Fig. 168, but its connections are different. The main current from the ship's supply is brought to the usual terminals, and the two bottom right-hand terminals connect as before to the battery, but the line current for the motor is taken off the two bottom outside terminals.

The battery can be charged at normal or maximum rate, or discharged through the board resistance at maximum rate, without having the machine running, but the machine cannot be run unless the battery is also in circuit, either on charge from the mains, or else off charge and supplying current to the machine.

The motor generator, in fact, is designed to run off the battery, not off the ship's mains.

The ½ K.W. Transformer.—This transformer is air cooled. It has a closed iron core of three limbs made up of lapped stampings. The primary and secondary windings are superposed on the middle limb and are enclosed in an ebonite case (see Fig. 174). It has one ratio only, namely, 110 to 5700 volts.

The ½ K.W. Transmitter.—This combination apparatus is shown in Fig. 175. A frame made up of ebonite rods and brass end plates, encloses a battery of six Leyden jar type condensers, the two metal end plates making connection respectively to the inner and outer conducting surfaces. A spiral of 16 turns ¼-inch copper tube is wound over the ebonite rods and is used as an auto jigger, part of the spiral forming the jigger primary, and the whole of the spiral the jigger secondary. As in all high frequency primary circuits, one end of the jigger primary, the bottom end of the spiral, connects to one pole of the condenser battery—the bottom end plate. The other end of the jigger primary connects to a spark gap and thence to the other pole of the condenser. In Fig. 175 the spark gap is shown mounted on the top end plate of the frame.

This arrangement provides an alternative plain discharger gap, which can be used instead of the disc discharger described above.

When, however, the disc is used, the flexible cable P runs

from the spiral to one electrode terminal of the disc, and the circuit is completed by another flexible cable, which runs from the second electrode terminal to the clamping nut under the lower ball of the plain discharger. The plain discharger can also be used with advantage as a safety gap across the disc electrodes. When the length of the gap is near the spark limit, it is useful for tuning up, as the spark leaves the plain discharger for the disc when the disc electrodes are set at the

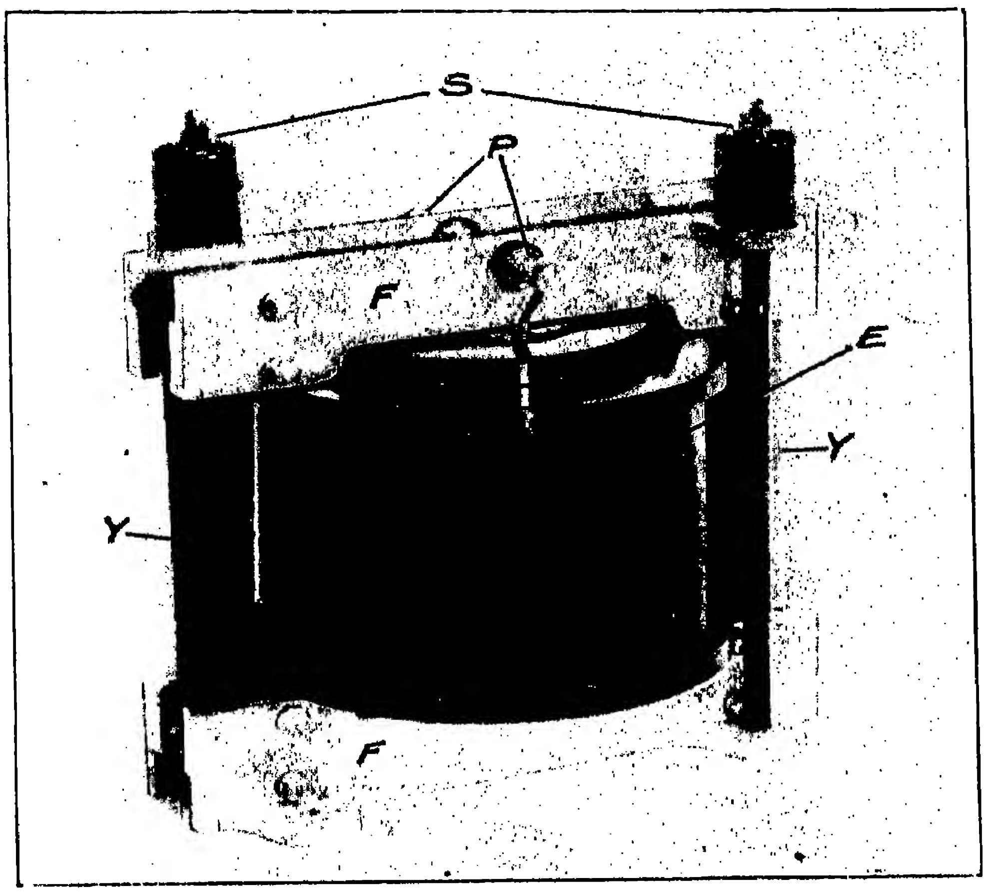


FIG. 174.—THE ½ K.W. TRANSFORMER.

E, Ebonite Case of Transformer Secondary Winding.—F, Aluminium Frame. —P, Primary Terminals.—S, Secondary Terminals.—Y, Yoke.

right phase position. The earth connection is made at the common junction of jigger primary and condenser.

A flexible cable similar to P—not shown—is used to connect the free end of the spiral S, to whatever external aerial tuning inductance is necessary to bring the aerial circuit into resonance with the primary wave length. A further cable runs from the inductance to the insulated terminal marked A, into which the aerial is plugged.

The condensers are glass tubes of special quality which

are coated inside and out with electrically deposited copper. The height of the copper on the tube is determined by careful calibration before plating, so that all tubes have as nearly as possible the same capacity and are therefore interchangeable. If one breaks down another can be put in its place in the primary circuit without fear of the wave length being

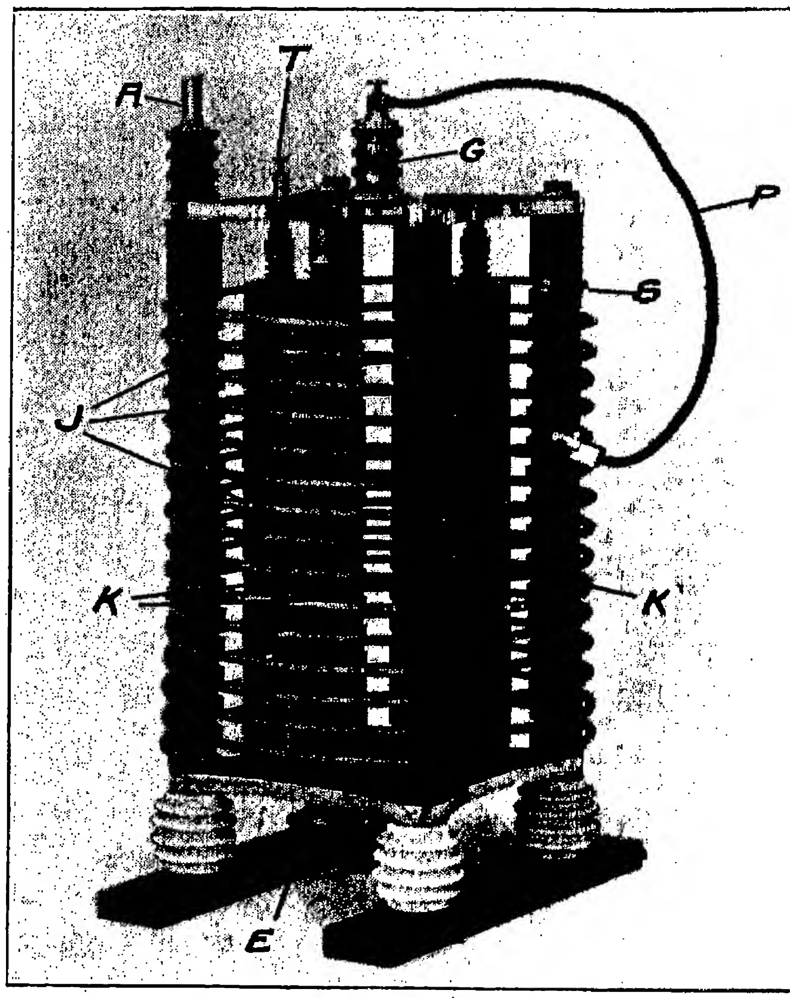


FIG. 175.—THE ½ K.W. TRANSMITTER.

A, Aerial Terminal.—E, Earth Terminal.—G, Spark Gap.—J, Copper Spiral Jigger Winding.—K, Condenser Tubes.—P, Jigger Primary Connection. —S, Free end of Jigger Secondary.—T, Transformer Terminal.

appreciably altered by the change. The coppered tube is shellaced all over except at the places of electrical contact; the end is plugged and sealed, and the rod connection from the inside coating is fitted with a patent screw cap, which locks the tube in the bank so that it is not disturbed by heavy vibration. At the same time the operation of taking out a broken tube and putting in a new one can be quickly and easily done. The condenser battery is contained in the jigger former for the sake

of compactness. It is not, however, the best place for it electrically, and later sets with a higher efficiency have been made up, having the condenser and jigger as two distinct units.

To obtain a good spark, the capacity of the condenser together with all the low frequency inductance, namely that of the alternator and transformer, have to impress a natural frequency on the circuit of a value corresponding to the frequency of the E.M.F. generated by the alternator. No separate low frequency tuning inductance is provided, and as the small motor field regulator supplied is only designed to affect the speed—and therefore the frequency—to a limited degree, it would at first sight appear that the apparatus as a whole has a want of flexibility which on occasions may tell against its electrical efficiency.

A simple form of adjustment, however, is available which is quite effective over the maximum range likely to be found necessary in practice.

If, instead of sparking the set at that position in the half cycle at which the alternator gives the condenser a maximum charge, some other position is chosen, then it is found that the inductance required to tune the low frequency circuit so as to obtain the best spark, varies with the sparking position.

Then suppose as a result of changing tubes in the condenser bank some small change in total capacity has resulted, which requires a converse change in low frequency inductance in order to maintain resonance, or that there has been some variation in speed due to the machine heating up, or the battery volts falling which would equally affect resonance, then if the available inductance is not adjustable, all that has to be done is to alter the spark phase position to suit the new conditions.

To do this, the disc box carrying the electrodes,—or the disc box cover, as the case may be,—must be rotated a few degrees right-handedly or left-handedly, until the best sparking position is found by trial.

The transmitter is required to give the two wave lengths of 300 metres and 600 metres, but it is continuously adjustable up to about 750 metres. The total inductance of the spiral is about 30 mhys. With 6–800 cms. condenser tubes, the 300 metre primary tapping is about four turns from the bottom, and the 600 metre tapping about 12 turns from the bottom. Additional aerial tuning inductance is nearly always required for the 600 metre wave, but not for the 300 metre wave.

CHAPTER III.

THE 1½ K.W. AERIAL.

Aerials—T aerial—Inverted L aerial—Method of measuring—Spreader—Strain insulators, ebonite rod—Strop insulators—"Bradfield" leading-in insulator—Aerial trunks—Soldering—Tuning transmitting circuits—Wavemeter—Long wave—Short wave.

SHIPS' aerials are of two kinds, being either in the shape of the letter T (Fig. 176 (*a*) or in the shape of an inverted L (Fig. 176 (*b*)).

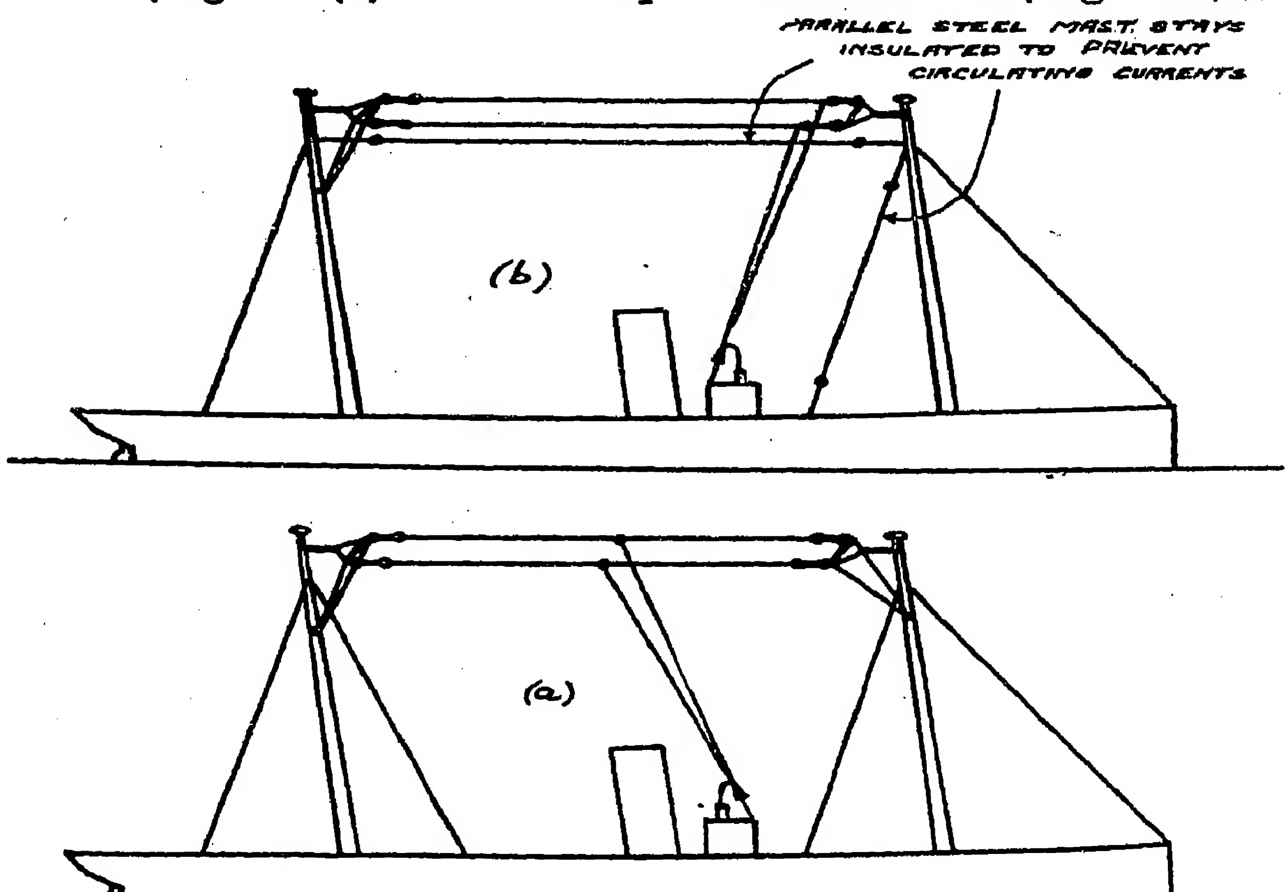


FIG. 176 (*a*) and (*b*).—Marconi "T" and "Inverted L" Aerials.

The former type is preferred for the equality of range all round attained by its use, while the latter is preferred for its greater

adaptability in erection. The size of the aerial is limited by such considerations as the height and distance separating the ship's masts, and the type of aerial is chosen in accordance with its adaptability to the position of the operating cabin, ship's funnel, stays, etc. On the great majority of ships the whole distance between the masts may be utilised for the aerial, because the natural wave length of such an aerial is still less than that of the longer wave used in agreement with the regulations of the international convention. For the production of the short wave, the aerials must almost invariably have their capacities decreased by means of a condenser in series, and this lessens the radiative power of the apparatus. The longer wave is the one most often used, whilst the shorter one is merely installed to conform with the regulations. As already stated, the natural wave length of the aerial is approximately between four and five times its length, so that in cases where the length of aerial is considerably less than 200 feet, the addition of a condenser in series for the short wave is unnecessary. In the case of the White Star liner *Olympic*, the distance between the two masts is so great that a certain amount of rope has to be used at the ends of the horizontal span, otherwise a series condenser would be necessary even when working on the long wave.

Where the masts are high and the funnel low, and the wireless cabin is situated forward of the funnel, a T aerial may be advantageously fitted, but under any other circumstances the inverted L aerial is generally found to be more convenient.

If the T-shaped aerial is used, it is found that no difficulty is experienced with respect to the horizontal setting of the spreaders to which the ends of the aerial are attached, but if an L aerial be used there is a tendency for the spreader at the free end to swing into a vertical position, which, apart from its unsightly appearance, introduces the risk of becoming entangled with flags, etc. In the latter case it is necessary to use steadying guys, and as a consequence insulators must be inserted between the ends of the aerial and the spreader. If the T aerial be used, full advantage may be taken of the distance between the masts, by connecting the wires to the spreader and inserting the insulators between the latter and the mast.

The Spreader consists of an ash pole thicker in the centre than at the ends, 12½ or 15 feet in length, fitted at the ends

with light malleable iron double-lugged bands. A bridle of $2\frac{1}{2}$-inch tarred hemp rope fitted at the ends with a thimble, is connected either direct to the lugs of the spreader-bands or

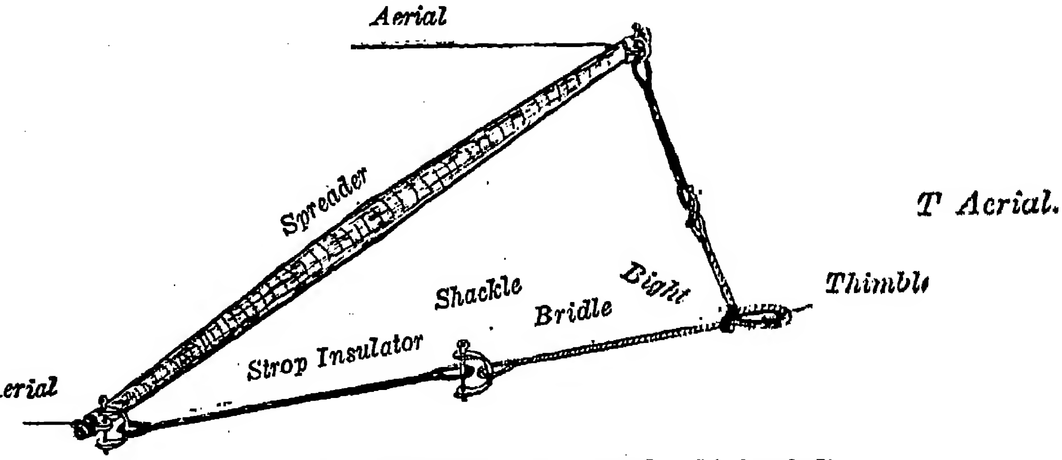


FIG. 177.—Spreader and Bridle (T Aerial).

else to the ends of strop insulators, the other ends of which are attached to the spreader. The bight of the bridle is fitted with a thimble, and the length of rope is such that the distance between the bight and the spreader is not more than 6 feet or

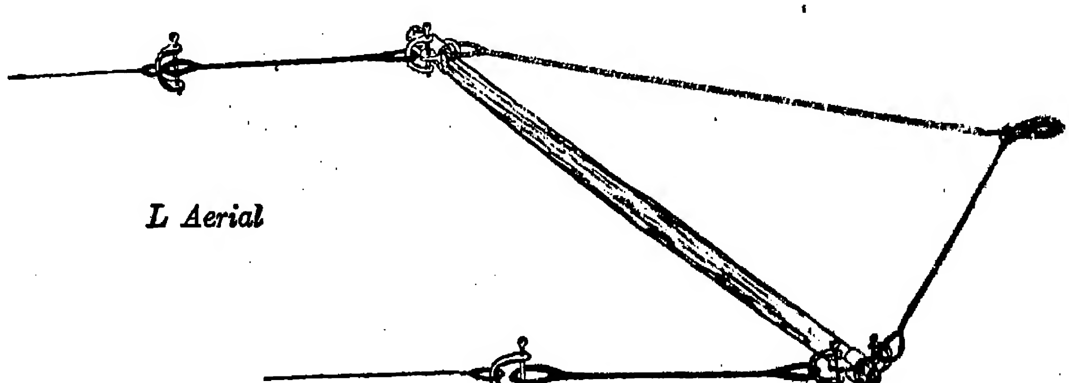


FIG. 178.—Spreader and Bridle (L Aerial).

less than 3 feet. Figs. 177 and 178 show the arrangement of the spreader and bridle for a T- and L-shaped aerial respectively.

Strain Insulators.—The aerial must be thoroughly insulated from the ship. For this purpose three principal forms of insulators are used. Strop insulators are used to insulate the ends of the aerial at the points of suspension. Strain ebonite rod insulators are used to insulate any aerial guys that may be used, and a special form of insulator is used for leading the lower end of the aerial into the operating-room.

The strop insulators are made of cord covered with rubber and vulcanised, and are fitted with a thimble at either end. Those used with the 1½ k.w. set are 3 feet in length. An occasional coating of bitumastic solution is found useful as a protection against rain. Complete and full instructions regarding these insulators are generally sent out with them. Fig. 178 shows the appearance of this type of insulator.

The strain rod ebonite insulators are supplied in pairs.

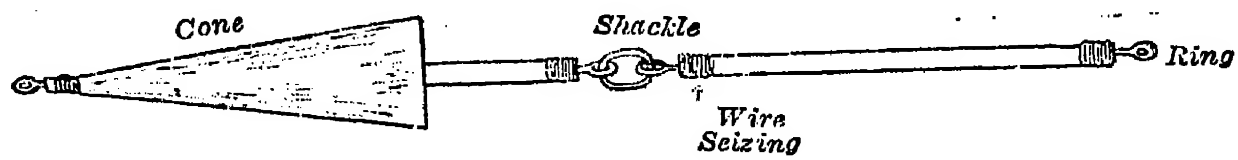


FIG. 179.—Ebonite Rod Insulator (Coned and Shackled).

Each rod has a ring screwed into each end, the rod being seized with wire to prevent splitting. One rod in each pair is fitted with a metal cone, as shown in Fig. 179. The down leads of the aerial are usually held in the required position by means of stays, a pair of rod insulators being inserted between the aerial and the rope in such a manner that the apex of the cone is pointing upwards, the cone thus serving

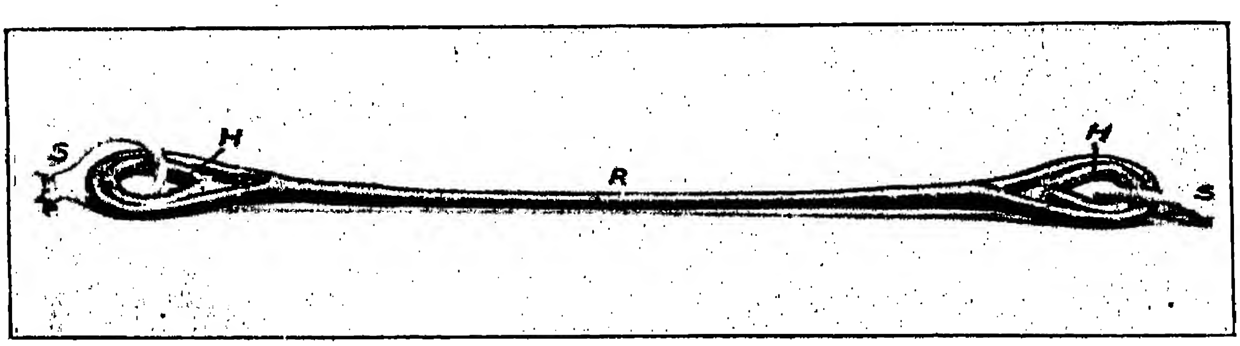


FIG. 180.—STROP INSULATOR.

R, Insulator Proper.—S, Galvanised Iron Shackle.—H, Heart Thimble.

to protect the insulator, through a certain part of its length at least, from rain.

The Leading-in Insulator.—This insulator, known as the "Bradfield" insulator, is shown in Fig. 182 and in section in Fig. 181.

R is a ½-inch steel rod which passes through a long ebonite tube, E, of 1½ inches outside diameter. Each end of the rod is threaded, the lower end being fitted with a brass socket, S, supplied with a wing nut, W, and the upper end being

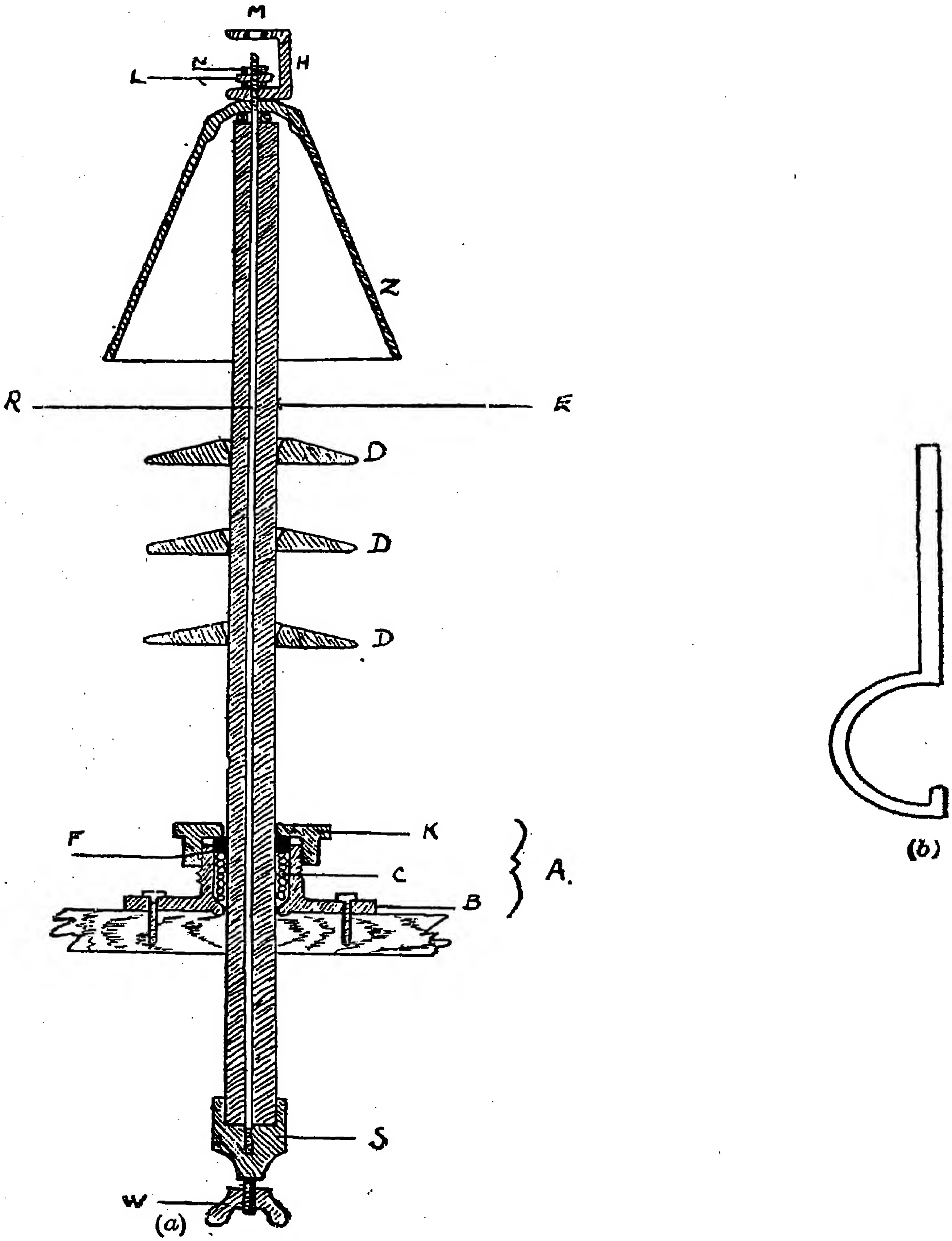


FIG. 181 (a) and (b).—"Bradfield" Leading-in Insulator and Key.

supplied with a shackle head, H, a double terminal brass lug, L, and lock nuts, N. A zinc cone, Z, is fitted over the steel rod and rests on the top of the ebonite tube, being held firmly in position by means of the lock nuts, the joint being rendered watertight by means of an asbestos washer. The cone keeps part of the insulator dry under almost any weather conditions. Three ebonite discs, D, known as anti-spark discs, are fitted at intervals along the tube, and assist in preventing sparking over the surface in wet weather. The insulator is led into the cabin through a stuffing box, A, which consists of the following parts :—B is a hollow casting through which the tube passes, the space between the inner face of the casting and the tube

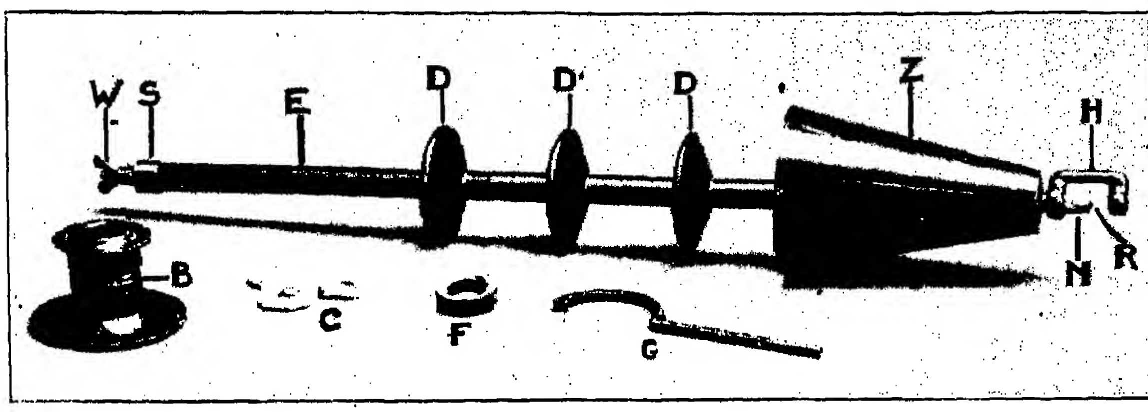


FIG. 182.—BRADFIELD LEADING-IN INSULATOR NO. 1.

B, Stuffing Box.—C, Asbestos Packing Rings.—D, Anti-spark Discs (ebonite).—E, Ebonite Tube.—F, Ebonite Ring for Stuffing Box.—G, Gland Key.—H, Iron Shackle.—N, Brass Nuts.—R, Steel Rod.—S, Brass Terminal Socket.—W, Brass Wing Nut.—Z, Rain Cone.

being occupied by seven asbestos packing rings, C. An ebonite ring, F, fits over the asbestos rings, pressure being brought to bear on it, for the purpose of packing the asbestos tight, by means of a flanged cap, K, which screws on to the outside of the casting B. K has four notches cut round its periphery, and the gland key, shown in Fig. 181 (*b*), is used to screw it hard home, in order to fix the insulator in a rigid position through the roof or the side of the cabin, as the case may be. The casting, B, is firmly fixed by means of four coach screws.

The lower ends of the two aerial down leads are given a turn or two round the shackle head, H, after having been

passed through the eye, M, and are made fast in the double brass lug, L, by means of two screws.

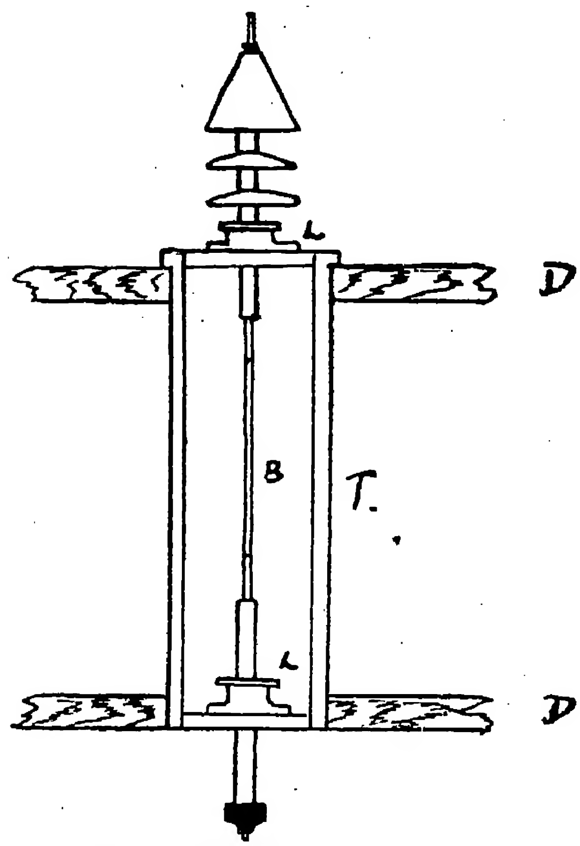


FIG. 183.—Aerial Trunk.

Aerial Trunks.—In cases where the operating-room is below the top deck, it is sometimes necessary to provide an "aerial trunk" to carry the aerial through the intervening decks. Fig. 183 shows such an arrangement. T is a wooden trunk which must not be less than 10 inches across, DD being two decks between which the trunk is fixed. A separate leading-in insulator with stuffing-box is fitted through each deck as shown at L, L. The lower one, of course, does not need a protecting cone. A threaded metal tube, B, is used to connect the steel rods of the two insulators, this being preferred to cable, as there is no possibility of slack taking place and contact being made with the inside of the trunk. Doors are let in the side of the trunk in order that the insulators may be accessible for inspection. It is also occasionally found necessary to use such a trunk where the aerial has to be carried through an awning.

Fitting of Aerial.—Having decided which type of aerial is to be installed, it becomes necessary to obtain the exact measurement of the distance between the masts, and the distance between the top of the wireless cabin and the middle of the horizontal span if a T aerial is to be used, or the distance between the top of the wireless cabin and the mast-head if an L aerial is to be used. These details may be obtained from the builders' rigging-plan or by actual measurement. The distance between the masts, less 5 per cent. for the stretching of the wire and 14 feet allowance for the space taken up by the bridles, should then be marked out on the deck. If an L aerial is to be used, a further 3 feet must be deducted to allow for the insulators at the free end. From the centre

point of this marked distance, the distance between the top of the wireless cabin and the centre of the horizontal span may be marked off in either direction for a T aerial. Then two lengths of wire are required equal to the length from either end to the centre point; and two lengths equal to the length from one end to the centre, plus the distance from the centre to the point showing the distance from the horizontal lead to the wireless cabin, for a T aerial. For an L aerial two lengths are required, each equal to the total horizontal span plus the distance from the mast-head to the cabin.

For a T aerial the following illustration may be better understood :—

FIG. 184.—Measurements for T Aerial.

AB represents the distance between the masts less 5 per cent. and 14 feet. C is the centre point. CD represents the distance between the centre of the horizontal span and the top of the wireless cabin. Then the following wires are required: Two equal to AC and two equal to BD.

For an L aerial, the following illustrates the method :—

FIG. 185.—Measurements for L Aerial.

AB represents the horizontal distance as before, less an additional 3 feet. AC represents the distance between the mast-head and the top of the wireless cabin. Then the following wires are required: Two equal to AB plus AC.

In making the measurement between the house and the horizontal span, in either case allowance must be made for any extra length required for the staying off of the aerial from parts of the rigging, etc. As the ends of the wires have to be seized round thimbles an allowance of, say, 6 inches, must also be made for each thimble. Fig. 186 shows how and where the thimbles should be fitted in the case of the T aerial. One end of the longer pieces is taken round a 1½-in. heart thimble and seized with No. 20 soft copper wire, the seizing being afterwards soldered as shown at A. At the point B, about 4 inches from the point corresponding to C in Fig. 184, another heart thimble is seized, a third one being fixed at the

point C in Fig. 186. A similar thimble is seized at one end of one of the shorter lengths D, and another one about 4 inches from the other end, E. The remaining end, F, of the shorter length is seized and soldered to the longer length at F. The three thimbles, B, C and E, are connected together by means of three galvanised iron shackles. It is thus seen that all strain is taken off the joint. The free ends of the T aerial are shackled to the iron rings on the spreaders, the ends of the bridle being also shackled to these rings. Care must, of course, be taken that the wires are taken outside all rigging before being connected to the spreader. Halyards are passed through the shackle at the bight of the bridle and pass through blocks at the mast-head. When all the connections have been made the aerial may be hauled aloft. and if the operations

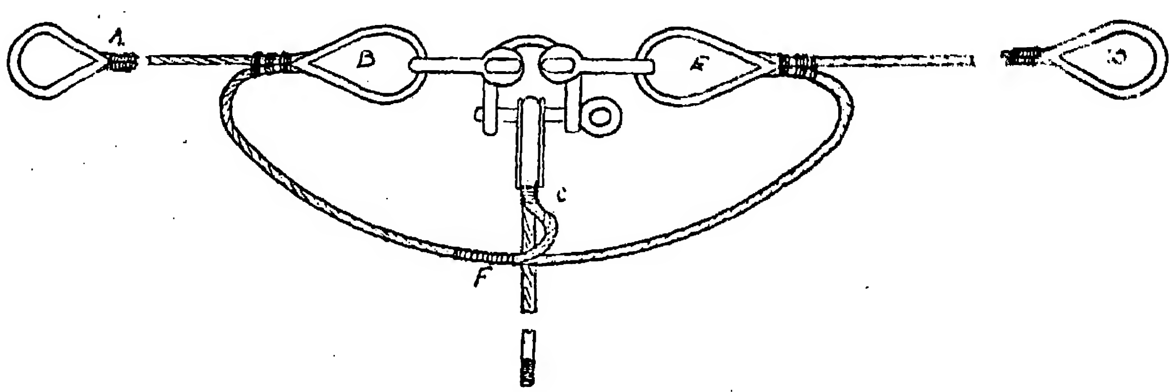


FIG. 186.—T Joint for Aerial.

have been carefully carried out it will be seen that the two parts are symmetrically disposed. Ebonite strain rod insulators attached to guy ropes may then be connected to suitable points on the down leads, and the lower ends of the guys made fast to some part of the deck, in such a manner that the down leads are kept clear of any obstruction.

Whenever a length of the aerial is running parallel to steel guys, care should be taken that the latter are insulated from the ironwork of the ship, otherwise considerable losses will ensue on account of induction.

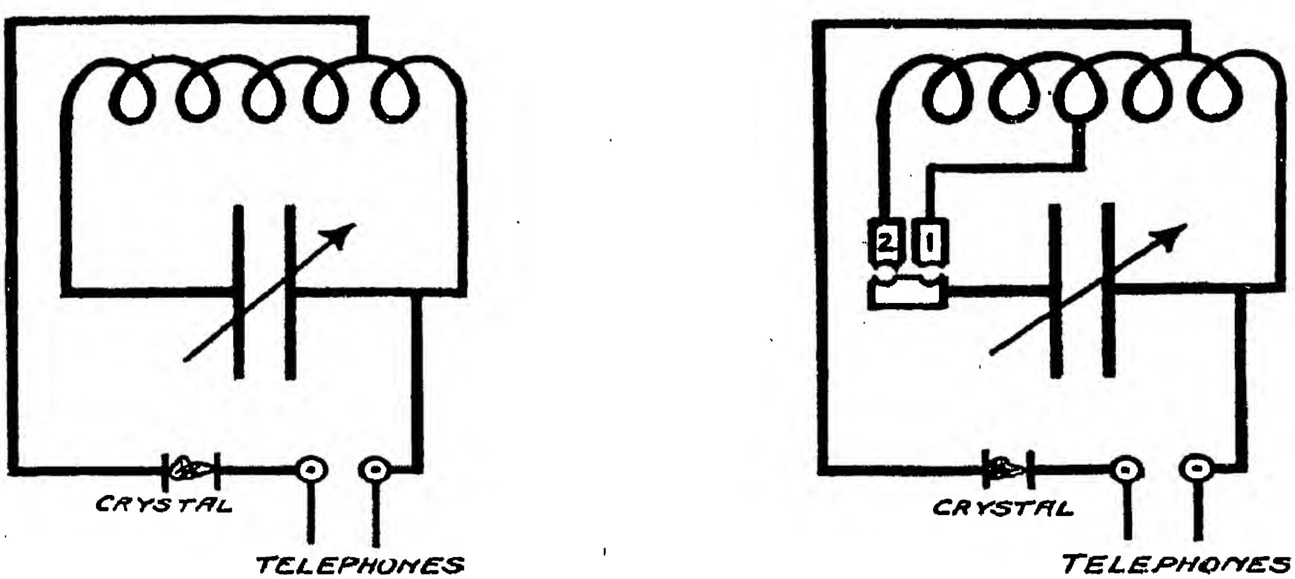
After the aerial has been hauled aloft and the down leads stayed, the loose ends of the latter may be cut to the final required length and connected to the brass double lug of the leading-in insulator. The wire between the points at which the insulated guys are attached and the Bradfield insulator should hang slack—but in such a manner that there is no risk

of it making contact with any part of the ship in swinging—in order that no strain may be put on the insulator itself.

Soldering.—When soldering the joints and seizing, it must be remembered that the solder will not hold unless the wire is clean. If the wire be cleaned with emery cloth, and if plenty of soldering paste be used, no difficulty will be found in making a good electrical joint. Of equal importance is the fact that heating weakens the aerial wire, so that in soldering the seizings, care must be taken to use as little heat as possible, and to avoid as much as possible heating the aerial wire itself in places where it will have to bear a strain.

Tuning the Transmitting Circuits.—For this purpose, unless the multiple tuner and detector be used in the manner described, a wave meter is necessary.

The Wave Meter.—A very convenient form of portable



(*b*)

FIG. 187.—Diagrams of Connections of Marconi Wave Meters Nos. 1 and 2.

wave meter is made and used by the Marconi Company. It consists of a variable condenser in series with an inductance coil, which usually gives two ranges by means of an intermediate tapping. The inductance coil is contained in the lid of a teak box, and the tapping, and the free end, are respectively connected in the circuit by means of a brass plug and sockets.

A carborundum crystal supported in a vertical spring clip, is used as a detector, in series with a telephone. Fig. 187 (*a*) gives the diagram of connections for a single-range wave meter reading from 130 metres to 800 metres, and Fig. 187(*b*) for a

double-range wave meter reading from 150 metres to 2500 metres. It will be noted that the carborundum crystal, by reason of its tapping connection on the inductance, does not take the full potential across the condenser, but only sufficient to give good signals. The disturbing effect of the crystal on the circuit is thus made as small as possible.

The instrument is carefully calibrated, and a card is supplied

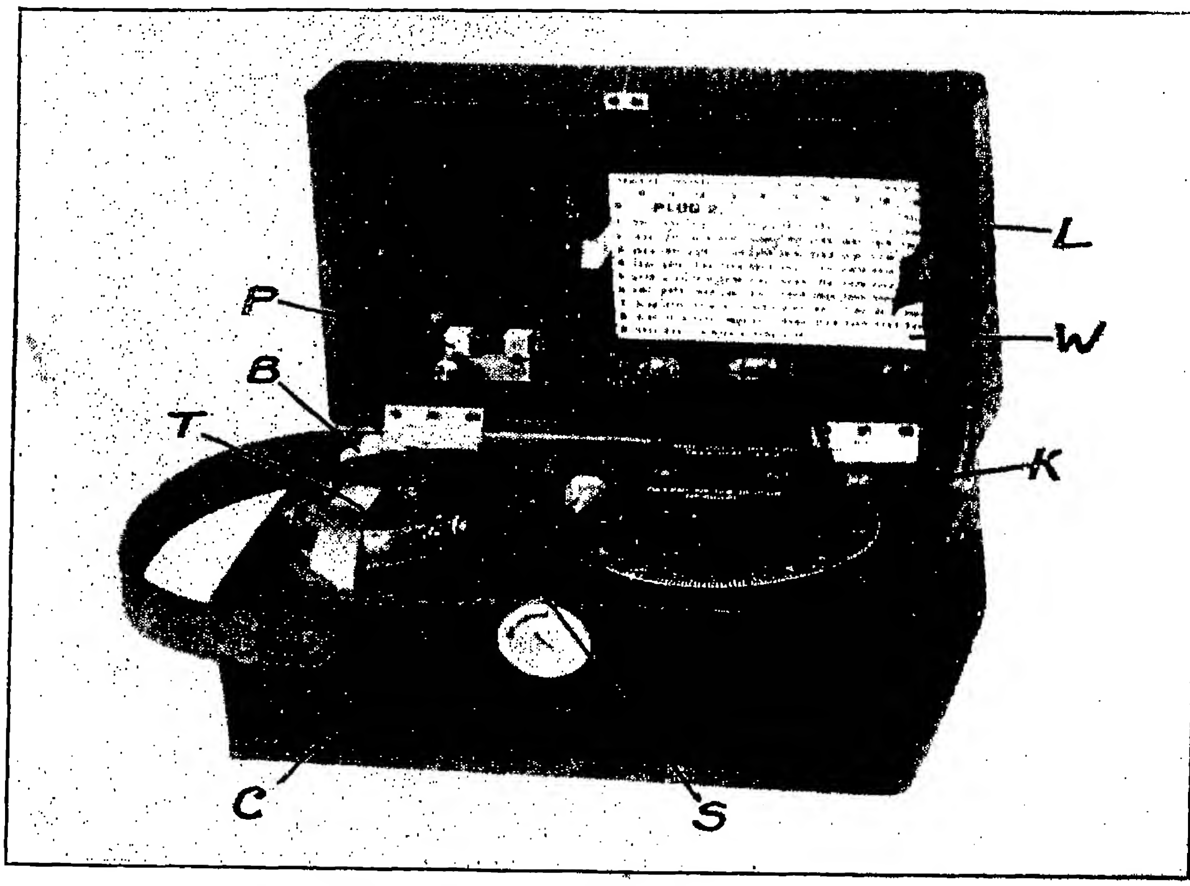


FIG. 188.—MARCONI WAVE METER NO. 2.

B, Crystal Box.—C, Crystal Clip.—K, Condenser.—L, Inductance Coil. —P, Two Range Plug Board.—S, Telephone Sockets.—T, Double Head Telephones.—W, Calibration Chart.

giving the wave lengths corresponding to the condenser readings when used with either of the two sections of inductance coil. Wearing the telephones, the person making the measurement walks a little distance from the circuit in which oscillations are being produced, and adjusts the condenser until the maximum strength of signals is obtained. The most accurate adjustment is obtained when the distance between the observer and the circuit under measurement is sufficient to produce *just audible* signals, as then any slight

deviation from the correct adjustment causes them to fail altogether.

The Plain Discharger transmitting circuit is tuned as follows :—

Tuning Low Frequency Primary Circuit.—It has been stated that the L.F. inductance should be adjusted until readings of 25 ampères and 75 volts are registered on the meters of the A.C. switchboard (page 152). This is, however, only a rough indication and is only possible when the D.C. is supplied at 100 or 110 volts pressure.

A better method of adjustment is to vary the inductance until a maximum spark is obtained between the electrodes with the machine running at the desired speed.

It is found that after the value of inductance for the maximum spark has been obtained, although a decrease of this value gives a greater ampèrage, the length of the maximum spark obtainable is decreased.

The final adjustment of the L.F. Primary Circuit may be left until the oscillating circuits have been tuned, when the L.F. inductance may be further regulated until the maximum glow of the tuning lamp is obtained.

Tuning Open and Closed Oscillatory Circuits.—Long Wave.—The secondary of the transmitting jigger is run up clear of the primary. The converter is then started, and the low frequency iron core inductance adjusted, as described on a 600-meter main condenser adjustment—that is to say, with main condenser banks in parallel. The speed of the converter is adjusted by means of the field regulator, until a steady spark is obtained during the transmission of a long dash. The variable high frequency sliding inductance is then adjusted until the reading on the wave meter shows that a 600-meter wave is being produced in the closed circuit. After seeing that all the choke in series with the tuning lamp is in circuit, the secondary of the jigger is lowered until it is just within the influence of the primary, and the earth arrester is temporarily shorted. With this very loose coupling, different values of aerial tuning inductance are tried, until a reading on the wave meter held outside the cabin near the aerial or earth-lead, indicates that a wave of the required length is being radiated. The tuning of the aerial may be checked by means of the tuning lamp. An adjustment of the choke is found which allows the lamp to glow just feebly.

If an increase and decrease of one turn of inductance lessens the brightness of the glow in each case, the circuit may be considered as tuned. If the results obtained are not sufficiently well marked, the coupling may be made a little closer. Finally, after removing the wire shorting the earth arrester, it is advisable to get into communication with some other station in order that the signals may be tested. A slight variation of the high frequency sliding inductance in the closed circuit, may be found to be necessary to obtain the best results.

Short Wave.—The lower end of the aerial must be disconnected from the aerial tuning inductance (A.T.I.), and be connected to one side of one bank of the extra condenser, the other side of the latter being connected to the upper plate of a separate earth arrester, as already described. The aerial must then be excited, and the capacity of the condenser varied, until the circuit is tuned for a 300-meter wave. The second bank of the condenser may then be built up to give the same wave length when "buzzed" with the jigger-secondary and earth-lead as far as the earth arrester, and then the two banks can be connected in parallel. The A.T.I. may then be reconnected to the lower end of the aerial (at the Bradfield insulator), and its value adjusted until resonance is obtained as denoted by the tuning lamp.

When varying the capacity of each bank of the short wave condenser, the zinc plates are removed one by one until the value of the condenser is obtained for the required wave. Comparing the area of the opposing plates with the total possible area, and taking account of the distance separating the plates, it is possible to rebuild the bank so that all the glass plates may be used, thus maintaining the original rigidity of the arrangement. A number of the zincs must, of course, be removed, but as these are so very thin their removal does not materially affect the outside dimensions of the bank. As this "short-wave condenser" has to stand considerable voltages, the use of the full number of glass plates is desirable, not only to preserve the rigidity of the whole, but also to provide sufficient dielectric strength. There should be at least three glass plates between each pair of zincs.

If the aerial is of such a size that it is capable of being tuned for the transmission of a 300-meter wave, using only four turns of jigger secondary, without resort being made to

the use of an extra condenser, this method is preferable to the one already described, as it facilitates changing over, and no loss, or at least very little, results from the cutting out of the three turns of jigger secondary, as the coupling—thus weakened—may be made closer again by sliding down the secondary of the jigger.

CHAPTER IV.

½ K.W. SETS.

The standard ½ K.W. set—D.C. circuit—Converter—Disc discharger—Low frequency tuning inductance—Transformer—Air core chokes—Main condenser—Strip jigger—Radiating circuit—Jigger with covered wire primary—H.F. primary tuning inductance—Aerial leading-in insulator—Receiving circuit—Plain tuner.

THE ½ K.W. SET.—A very efficient small-power set is often fitted on cargo boats and small passenger liners. This set differs from the 1½ k.w. in several constructional details, although the disposition of the pieces of apparatus and various circuits is very similar. The set has been designed to take up as little space as possible, and the greater part of the transmitting gear is contained in a small cabinet (see Fig. 189). As before, the various pieces of apparatus will be discussed in the order in which they appear in the circuits.

THE D.C. CIRCUIT.—This is the usual arrangement of double-pole main switch and cut-out, a converter, starter, and regulator. The starter and field regulator are of the iron-clad type. That is to say, an iron cover fits over the face of each, the regulating handles being brought through a slot in the casing. The converter armature is designed to run on a vertical shaft instead of horizontally, the machine thus taking up less floor space (Fig. 190). The top end of the shaft carries a ventilating fan, and a disc discharger contained in a chamber forming part of the carcase of the machine. The disc discharger consists of a corrugated ebonite plate, with brass rings clamped on its periphery, which carry eight equally spaced copper studs. As the disc rotates horizontally, these studs take the discharge from two copper electrodes mounted in an ebonite plate forming the roof of the disc chamber.

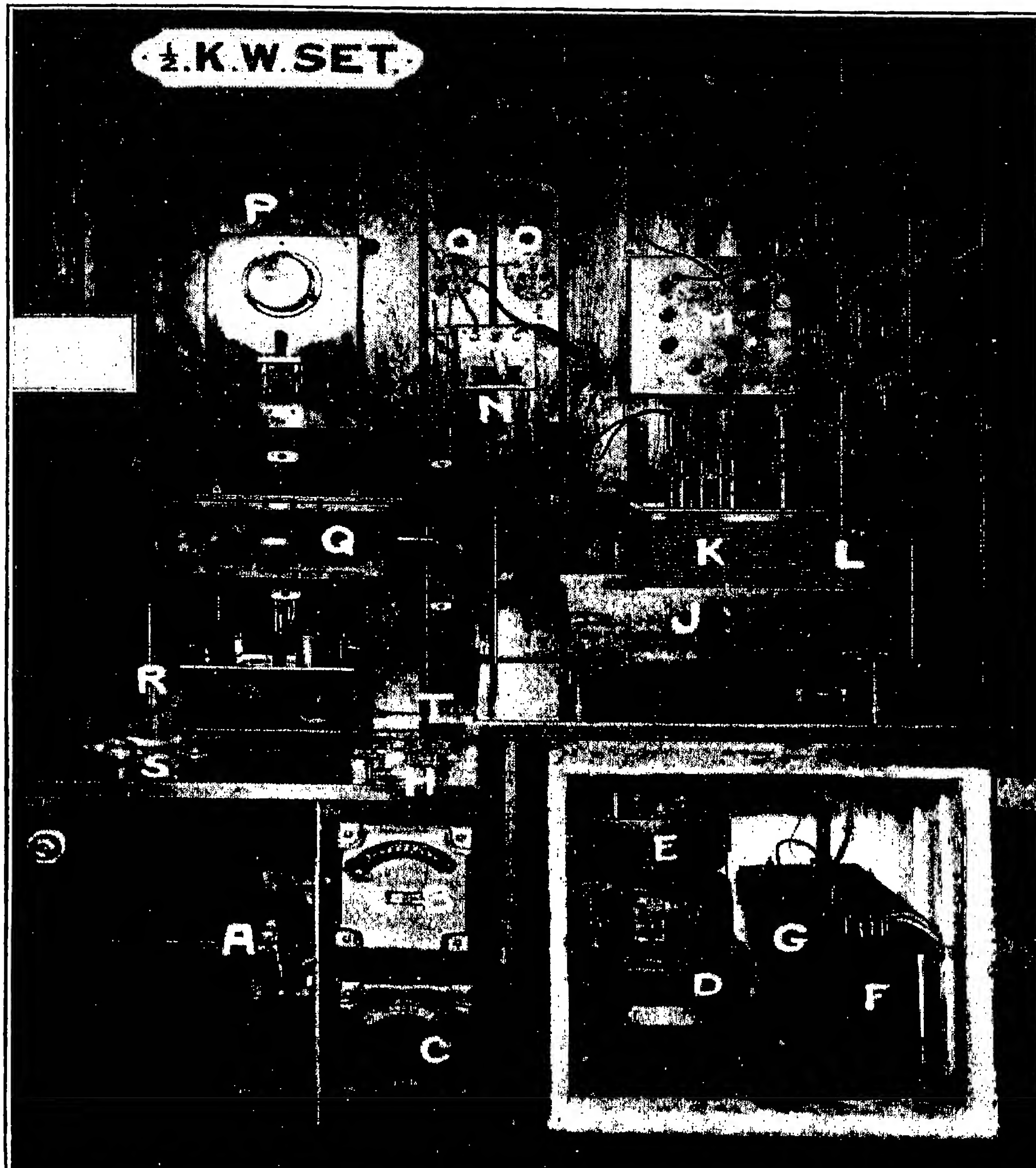


FIG. 189.—½ K.W. SHIP SET, INSTALLED AT MARCONI HOUSE.

A, Main Switch.—B Starter.—C, Field Regulator.—D, Rotary Converter—E, Disc Discharger.—F, Low Frequency Inductance.—G, Main Condenser.—H, Manipulating Key.—J, Jigger Primary.—K, Jigger Secondary.—L, Short Wave Extra Condenser.—M, Aerial Tuning Inductance.—N, Tuning Lamp.—O, Earth Arrester Spark Gaps.—P, A.C. Switchboard.—Q, Magnetic Detector.—R, Simple Tuner.—S, Telephones.—T, Buzzer.

(The transformer and choke coils are hidden behind the converter in the cabinet.)

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By slackening two nipping screws in the rim of the disc box, which allows the ebonite plate carrying the electrodes to be rotated on its seat, the electrodes can be given a lead or lag on the disc studs so that any required adjustment of spark phase can be obtained. The spark phase is shown by

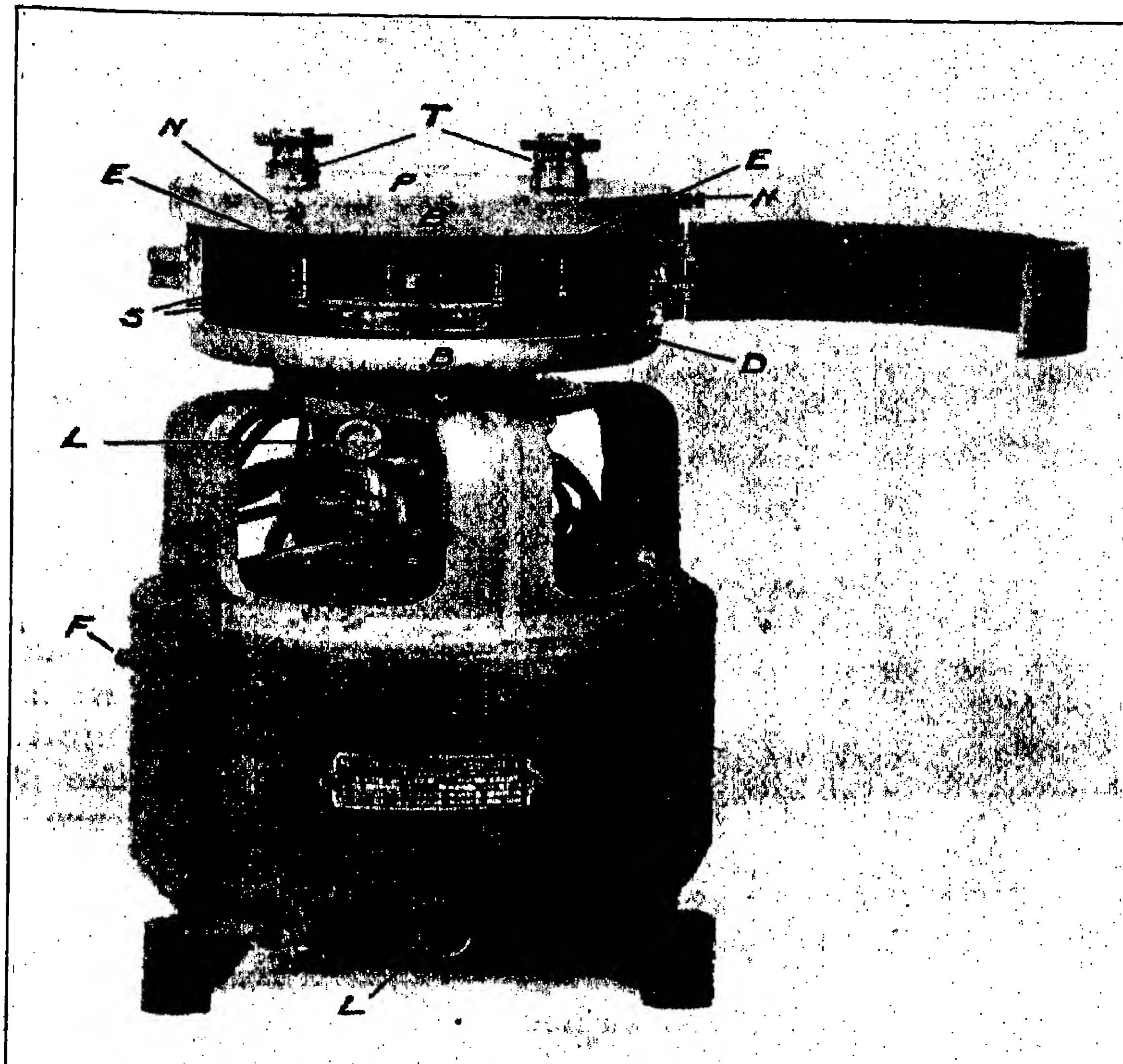

FIG. 190.—THE ½ K.W. CONVERTER.

B, Disc Box.—D, Disc.—E, Electrodes.—F, Field Terminal.—L, Stauffer Lubricator.—N, Nipping Screws.—P, Electrode Plate. —S, Disc Studs.—T, Electrode Terminals.

an index on the plate, which moves along the edge of a scale of phase degrees on the disc box.

The fan maintains a circulation of air through the disc chamber and prevents overheating of the electrodes. Continuous sparking, however, causes them to burn away, and the

heavy brass terminals which carry them are therefore constructed to give a hand feed to the electrodes to compensate for wear. The commutator and slip rings are mounted near each other between the armature and the rotary spark disc. The machine has eight poles, so that four cycles of alternating current are produced for each revolution. The normal speed is 2250 revolutions per minute, so that a frequency of 150 cycles is obtained. As eight studs are used on the disc, the spark frequency is 300 per second. Best results are obtained as regards quality of note, steadiness of spark, and efficiency of sparking circuit, when the minimum spark gap between disc studs and electrodes is made as small as possible. But due allowance must be made for inequality of wear in different studs, and the fact that when the studs and electrodes are hot they expand. If the gap is too small they will touch, and get bent in consequence, and the note will be spoilt.

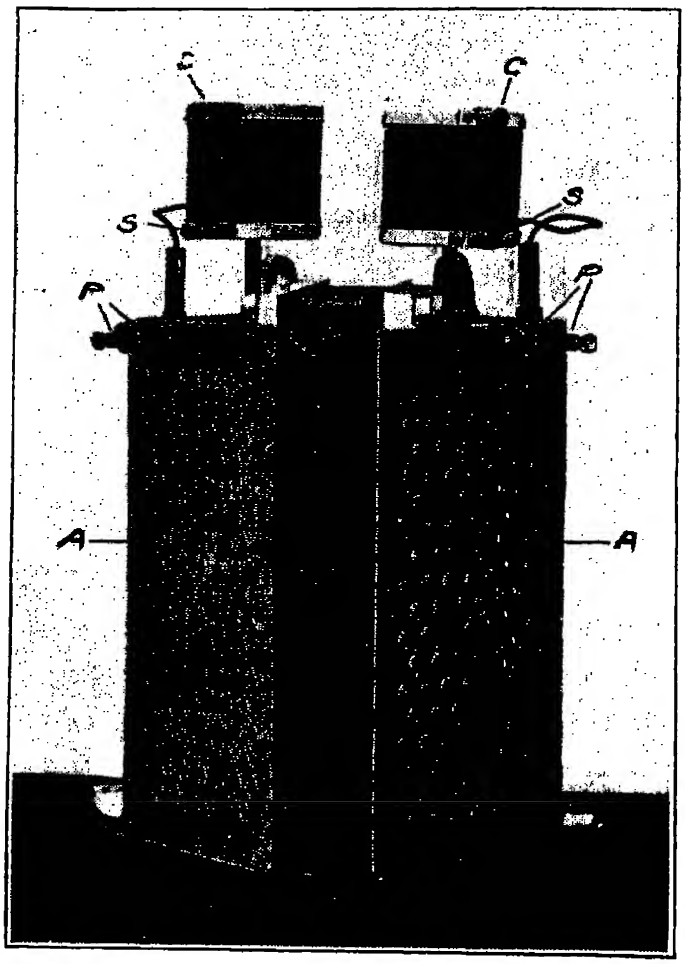

FIG. 191.—THE ½ K.W. TRANSFORMER.

A, Aluminium Frame.—C, Choke Terminals.—P, Primary Terminals.—S, Secondary Terminals.—Y, Yoke.

The ebonite electrode plate also must be kept perfectly dry and clean. If it does not receive this attention, a spark will be found to jump across the face of the ebonite to the earthed frame of the machine, a groove will be burnt in the ebonite, and a shut down will be necessary until the insulation is repaired.

A breakdown of this nature will sometimes start insulation troubles in some other part of the circuit.

THE LOW-FREQUENCY CIRCUIT.—This circuit contains a

small switchboard carrying a knife switch, fuse-ways, and ammeter, a manipulating key with telephone short-circuiting contacts, an iron-core low-frequency inductance, and the primary winding of a transformer. It is seen, therefore, that the magnetic key used in the $1\frac{1}{2}$ k.w. set has been dispensed with, this being on account of the lower current and voltage values dealt with.

The regulating inductance coil is wound on an iron core, and is supplied with six terminals arranged in a circle on one end instead of being arranged down the centre of one face of the container. With one connection made permanently to the terminal marked (1), the inductance is adjustable from ·005 henrys to ·0125 henrys.

The cartridge fuses used are of 20-ampère capacity.

The Transformer (Fig. 191) consists of superposed primary and secondary windings on a closed iron core, as shown diagrammatically in Fig. 192. Unlike the $1\frac{1}{2}$ k.w. transformer, only one arrangement of secondary can be used. The primary also is not adjustable. One pair, and not two pairs of primary terminals as shown in Fig. 191, is now standard practice. The coils are enclosed in ebonite casing, the whole being contained in an aluminium frame. The transformer is air-cooled instead of being oil-cooled.

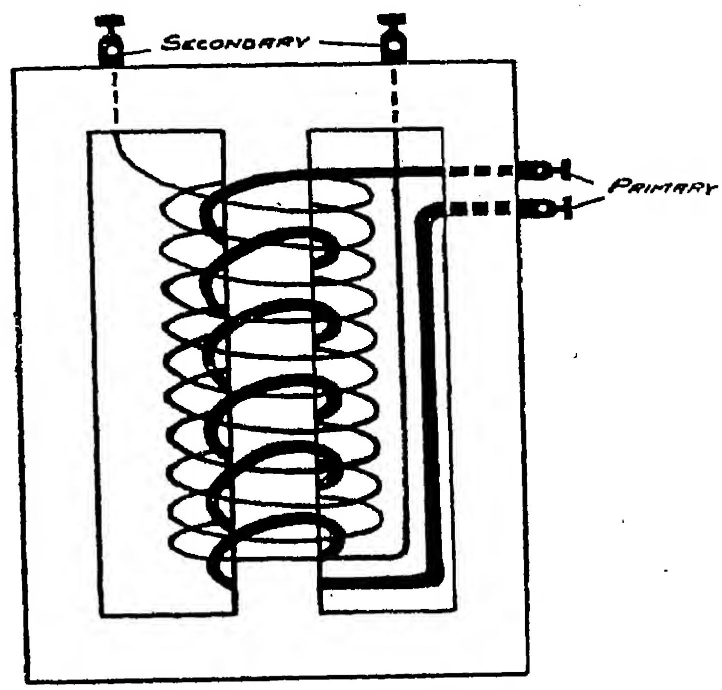

FIG. 192.—Core and Winding Diagram of $\frac{1}{2}$ K.W. Transformer.

THE H.T. AND THE CLOSED OSCILLATORY CIRCUIT.—This circuit contains the transformer secondary winding, the air-core chokes, the main condenser, and a variable high frequency inductance, the latter forming at the same time the primary of the jigger.

The Air-core Chokes consist of windings of enamelled wire on porcelain formers, which are mounted by means of bolts on the framework of the transformer.

The Main Condenser is of the same type as the $1\frac{1}{2}$ k.w. condenser but smaller. The zinc and glass plates are the same size, but there are fewer of them, and there are two sheets of glass between each pair of zincs. Instead of being separated into two banks in the container, the condenser is all in one bank with two main terminals. The capacity therefore is fixed and not variable as in the other sets described. All change of wave length of the circuit must accordingly be made by altering the inductance, which must be correspondingly large to cover the range required.

The Strip Jigger.—The jigger primary is therefore con-

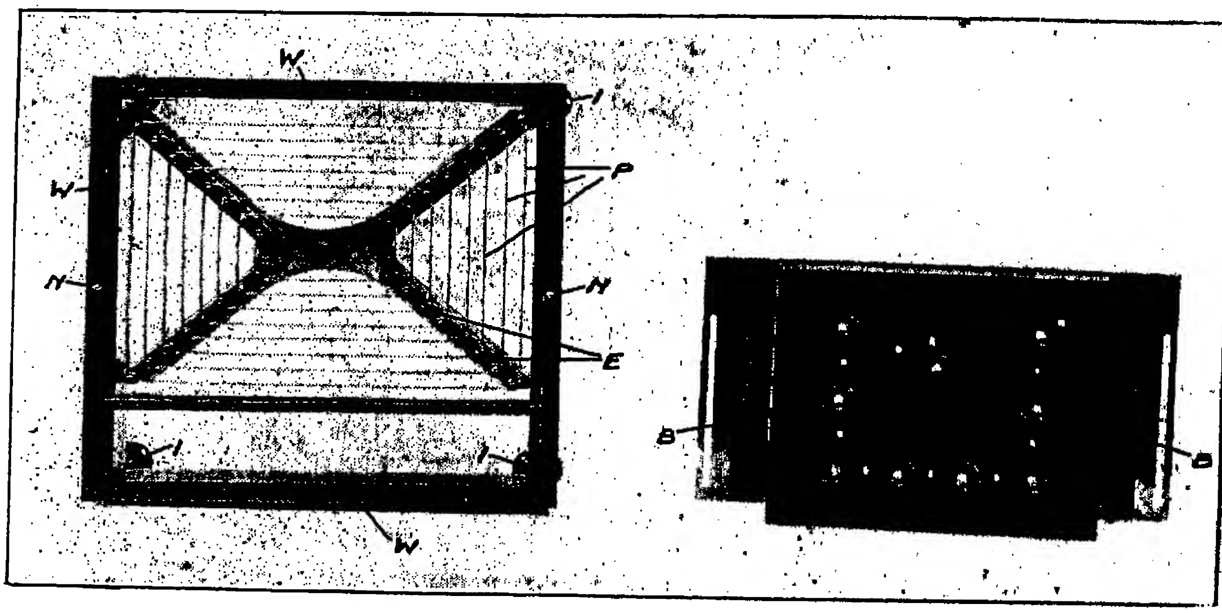

FIG. 193.—THE $\frac{1}{2}$ K.W. STRIP JIGGER.

A, Aluminium Spider.—B, Brass Slides.—E, Ebonite Supports.—I, Iron Feet.—N, Nipping Screws.—S, Secondary Box.—P. Copper Strip Primary.—W, Wood Frame.

structed of many turns of bare copper strip, see Fig. 193. The adjustment of the closed oscillatory circuit for the 300 and 600 metre waves are made by varying the points at which the leads are clipped to the primary. This combined inductance and primary is carried on an insulating stand, and placed on the top of the cabinet containing the transformer, main condenser, converter, and low-frequency inductance, and the leads to it consist of heavy flexible cable brought through ebonite bushes in the top of the cabinet.

The Radiating Circuit.—The jigger secondary consists of twenty-one turns of well-insulated but close-wound cable,

and is not boxed in. It has tappings arranged so that any number of turns from one to twenty-one can be put in circuit, by plugging into sockets on the front in the usual way.

The secondary slides over the primary in order to vary the coupling, and is separated from it by a sheet of ebonite.

The aerial tuning inductance is of similar construction to the jigger secondary, having its winding open to view. The total number of turns, however, is 10.

The Jigger with Covered Wire Primary.—A large continu-

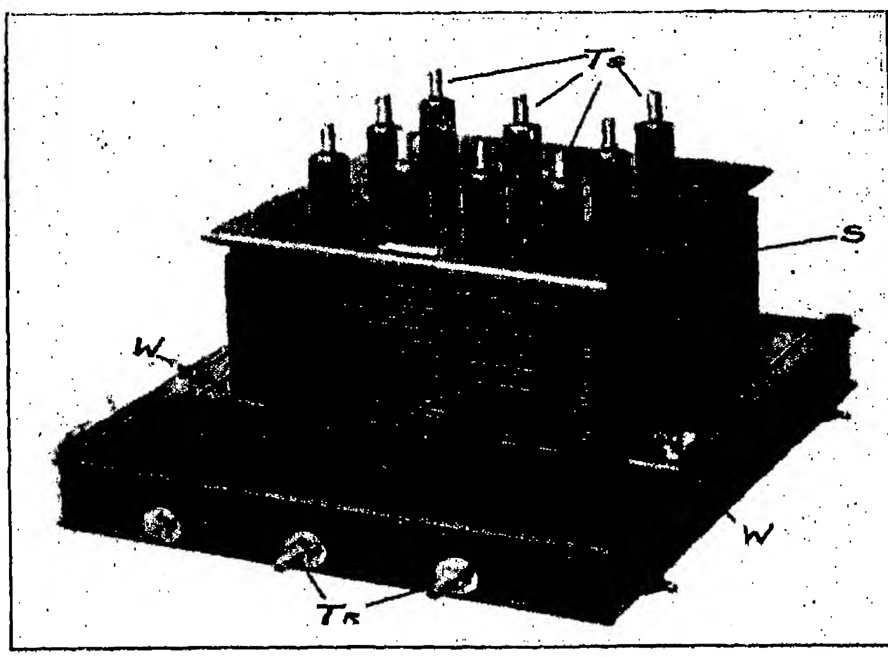

FIG. 194.—THE ½ K.W. COVERED WIRE JIGGER.

P, Primary Box.—TR, Primary Plug Socket Tapping Connections.—Ts, Secondary Plug Socket Tapping Connections.—S, Secondary Winding.—W, Wing Nuts.

ously adjustable inductance, such as is provided by a bare copper strip primary, is certainly very useful where considerable variation of an uncertain amount may from time to time be required; but when the working wave lengths are definitely fixed, and the capacities of the condensers used on different sets only vary within a few per cent. of a definite value—the necessity for so much adjustable inductance does not exist.

A ½ k.w. transmitting jigger with a covered wire primary has therefore been designed, Fig. 194, which simply provides one terminal for a fixed primary connection, and two plug

sockets for change-over primary connections, for the 300 and 600 metre waves respectively.

The plug change-over is time saving in adjustment, which is a distinct advantage. When it is necessary to alter the clip connection on the strip jigger in order to change the wave, the hand must be worked under the frame, and the supports are therefore made high enough to allow the clearance necessary. But this clearance is not required with the covered wire jigger, as the adjustments are made on the front. The primary box, therefore, rests on the bench, and the gain in head space above the jigger as a result is often of value on small ships. There is no alteration in the jigger secondary.

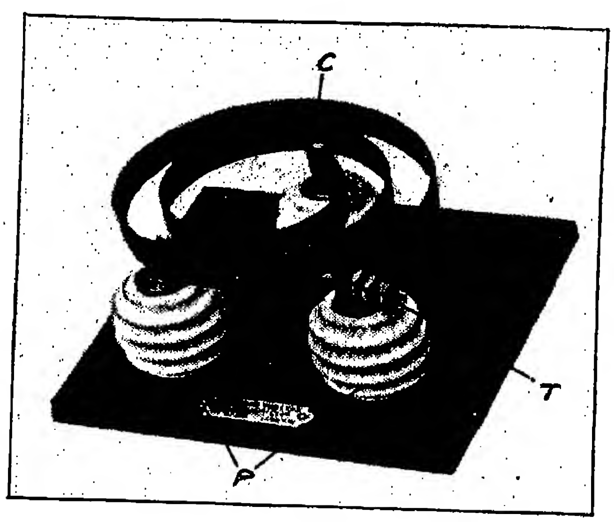

FIG. 195.—THE ½ K.W. H.F. PRIMARY TUNING INDUCTANCE.

C, Copper Strip.—P, Porcelain Supports.—T, Terminal.

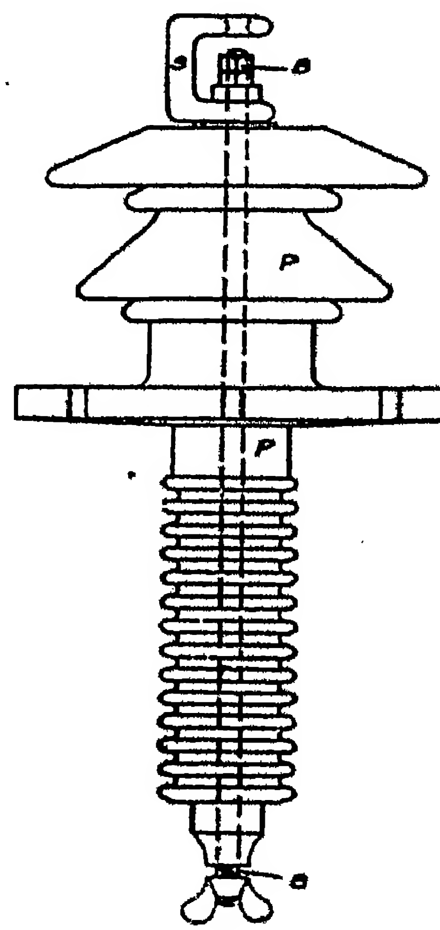

FIG. 196.—THE ½ K.W. AERIAL LEADING-IN INSULATOR.

B, Brass Rod.—P, Porcelain Body.—S, Iron Shackle.

H.F. Primary Tuning Inductance.—For final adjustment of wave length, and in order to cover any variation in capacity between one condenser and another, or the change in capacity of a condenser after repair, a small spiral tuning inductance is supplied for use with the covered wire primary, having a value of ·5 mhy. (see Fig. 195). A flexible cable with a

clip at one end and a plug at the other, is used for connecting the strip to one of the jigger primary plug sockets. The terminal at the end of the strip connects to one of the electrode terminals of the disc.

The Aerial Leading-in Insulator.—This is shown in Fig. 196. It is completely of porcelain without a joint, having a brass

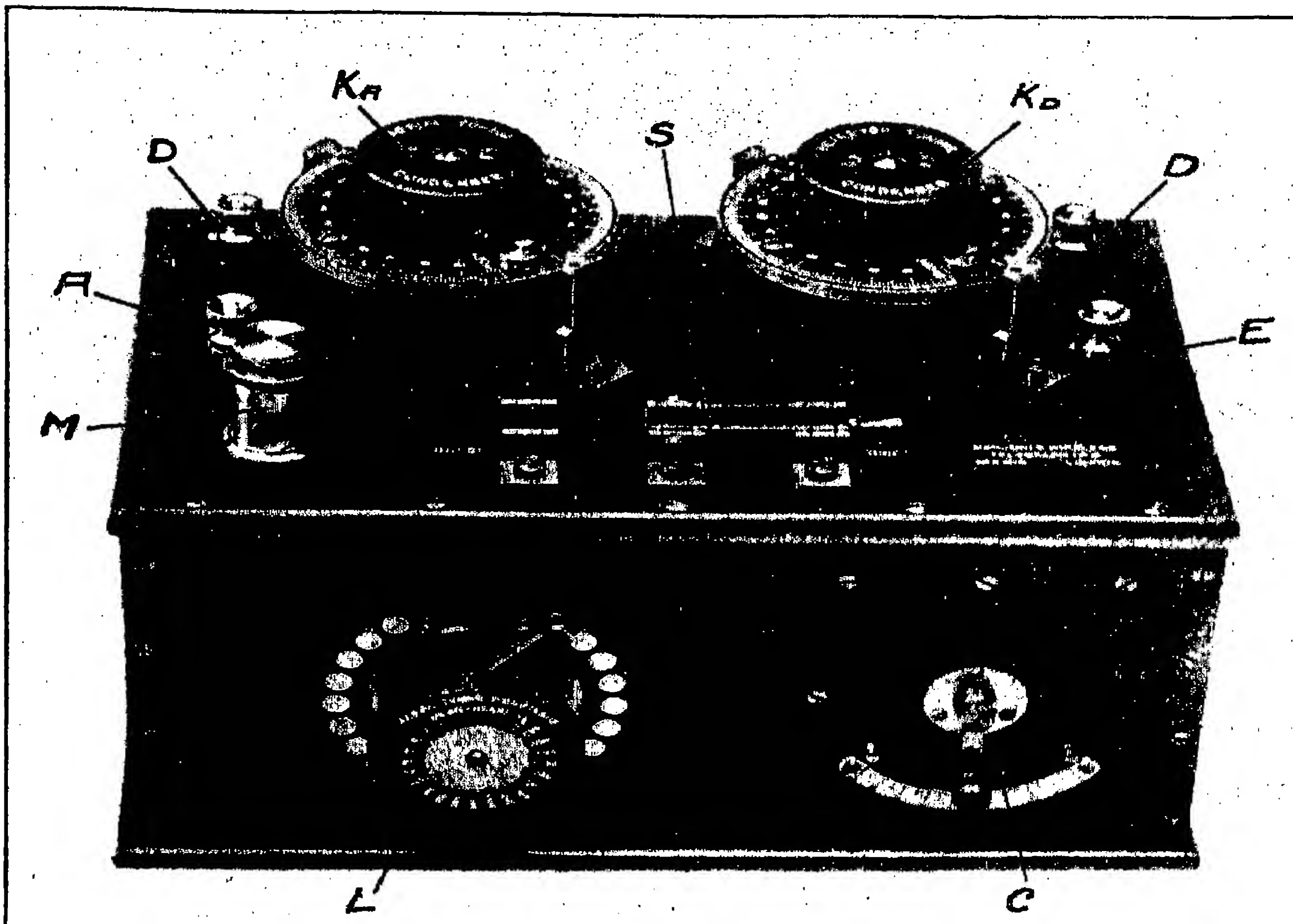

FIG. 197.—THE PLAIN TUNER.

A, Aerial Terminal.—C, Coupling Adjustment.—D, Detector Terminals.—E, Earth Terminal.—KA, Aerial Tuning Condenser.—KD, Detector Tuning Condenser.—L, Aerial Tuning Inductance Handle.—M, Micrometer Spark Gap.—S, Change-Over Switch "Std-bi" to "Tune."

rod down its centre, an iron shackle and brass nuts at the top, and a butterfly nut at the bottom. The rain cone and anti-spark discs of the "Bradfield" type, are replaced by moulded porcelain petticoats.

The Receiving Circuit.—The tuner used with the magnetic detector is of simplified construction and is therefore known as a "simple" or "plain" tuner (see Fig. 197). It has no

intermediate circuit. On the "tune" side the range of the detector circuit is less than that of the multiple tuner, but it more than covers all commercial wave lengths—reading from 250 metres to 1700 metres. On "stand-bi," the aerial circuit has sufficient inductance for the shortest ship's aerial to pick up press from Poldhu. The simple tuner then has only two variable condensers to adjust instead of three, and having

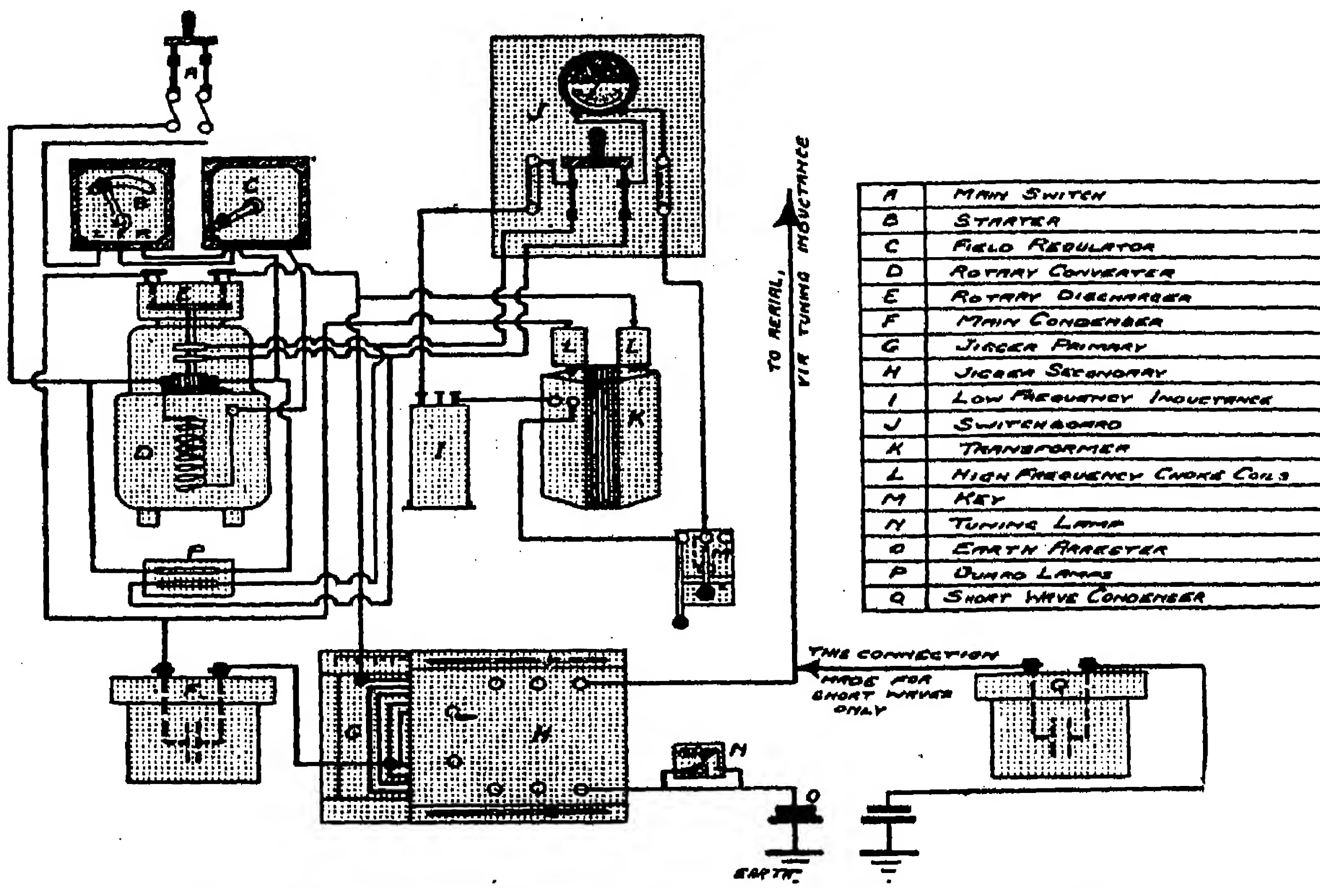

FIG. 198.—Connections of Transmitting Gear, ½ K.W. Set.

only one range it has no "tuning switch." Also the intensifier handle of the multiple tuner is replaced by a small arm on the front of the case, which moves over the face of a brass quadrant indicating the degree of coupling. The variable inductance and the change-over switch are similar to those of the multiple tuner. A complete drawing of the ½ k.w. transmitting connections is shown in Fig. 198.

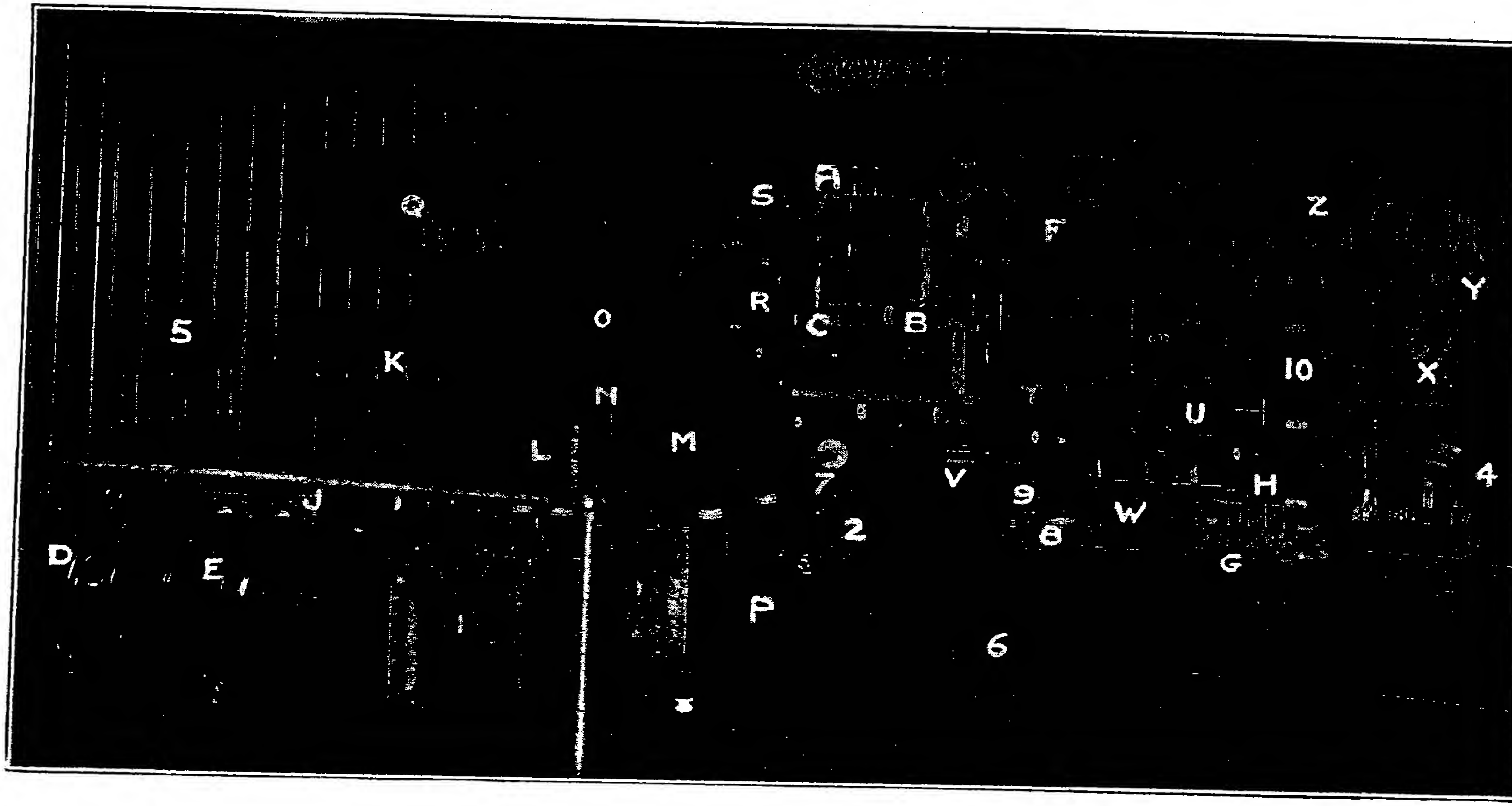

FIG. 199.—5 K.W. PLAIN DISCHARGER SET, AS INSTALLED AT MARCONI HOUSE.

A, Automatic Starter.—2, Switch for Same.—B, Motor Field Regulator.—C, Alternator Field Regulator.—D, Motor.—E, Alternator.—F, Double Panel Switchboard A.C. and D.C.—G, Manipulating Keys.—H, Double Magnetic Key.—I, Full Plate Condenser Units.—J, Transformer.—K, Air Core Choke Coils.—L, Spiral Inductance.—M, Discharger.—N, Jigger Primary.—O, Jigger Secondary.—P, Low Frequency Iron Core Inductance.—Q, Aerial Tuning Inductance.—R, Tuning Lamp.—S, Earth Arrester Spark Gaps.—T, Switch (two way).—U, Magnetic Detector.—V, Valve Detector.—W, Multiple Tuner.—X, Valve Accumulator Battery.—Y, Valve Accumulator Charging Board.—Z, Marine type Switchboard.—4, 10" Induction Coil.—5, Guard Lamps.—6, Extra Coil Condenser.—7, Buzzer.—8, Telephones.—9, Telephone Condenser.—10, Aerial Plug Sockets.

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CHAPTER V

5 K.W. SETS

5 k.w. "Plain Discharger" set—Motor generator—Starter—Switchboard—Graphite protecting rods—Iron core inductance—Double magnetic relay key—Transformer—Air core chokes—4 Cell main condenser—4 Cell Swiss commutator—No. 1 Spiral inductance—Transmitting jigger—Radiating circuit—5 k.w. "Battleship" set—8 Cell main condenser—8 Cell Swiss commutator—Transverse stud disc discharger—Plug primary transmitting jigger—Aerial tuning inductance—5 k.w. "Special" set—Single magnetic relay key—Low frequency tuning inductances—Air core chokes—Main condenser—No. 2 spiral inductance—Radial stud disc discharger—Skeleton jigger—Valve receiver—Accumulators for—Charging board—Crystal receiver No. 16—Balanced crystal working—Crystal receiver No. 26.

THE 5 K.W. "PLAIN DISCHARGER" SET.—The arrangements of the circuits in the different power sets is very much the same, the real differences only consisting of modifications in the various pieces of apparatus.

Starting with the transmitting gear illustrated in Fig. 199, and considering the circuits in the same order as was done in the case of the 1½ k.w. set, the first modifications are found in the direct current circuit. Instead of using a rotary converter for the conversion of the ship's direct current into alternating current, a motor-generator is employed. This consists of a motor and an alternating current dynamo coupled together, supplying power at a frequency of 70 cycles. A starter and field regulator are used in the motor circuit just as in the 1½ k.w. set, the starter, however, having slightly different connections. Fig. 200 shows the starter, and it will be seen that an additional electro-magnet is mounted on the slate face. This is an

overload release of such design that when the current exceeds a certain amount, the armature, C, is attracted upwards, and makes contact with the stop, T, thus short-circuiting the no-volt release and allowing the starting handle, H, to fly back to the "off" position. The force necessary to attract the armature is greater if the latter be further away, and this affords a means of setting the overload release to any value between certain limits. The lower end of the armature is supported on a slotted brass strip which has its lower end bent at right angles as shown at M. The position of this strip, which is marked with a scale of ampères, is adjusted with respect to the coil by means of the screw, D, so that any current exceeding the ampères shown on the scale is capable of causing the armature to be attracted.

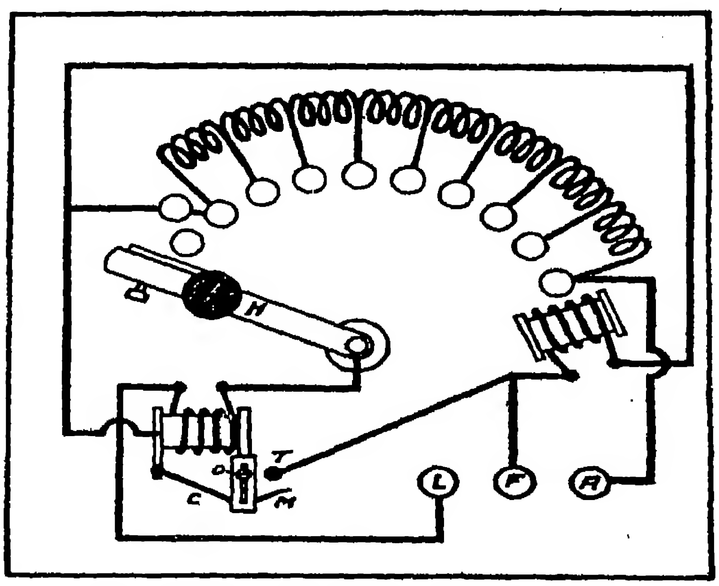

FIG. 200.—Starter, 5 K.W. Set.

In this set the main switchboard has an extra panel, which is supplied with voltmeter, ammeter, 100-ampère cartridge-fuses, pilot lamp, and D.P. knife switch, all these being used in connection with the direct current circuit. The generating part of the machine is somewhat different from the type of dynamo previously described, in that the part which revolves is the *field*, and the stationary coils disposed round the inside of the framework are the ones in which the alternating current is *induced*. It will be seen, therefore, that the alternating current is not taken from slip rings as before, but from two fixed cables which are led out from the stationary windings. Now the strength of the induced alternating current depends on the intensity of the revolving field, and means are supplied for varying this intensity. The revolving field coils are therefore connected through a pair of slip rings mounted on the shaft, and through a variable regulating resistance, to the direct current supply. The regulating resistance is very similar to the field regulator of the motor in appearance, and its use is obvious. The complete con-

nections between the mains and the main switchboard are shown in Fig. 201.

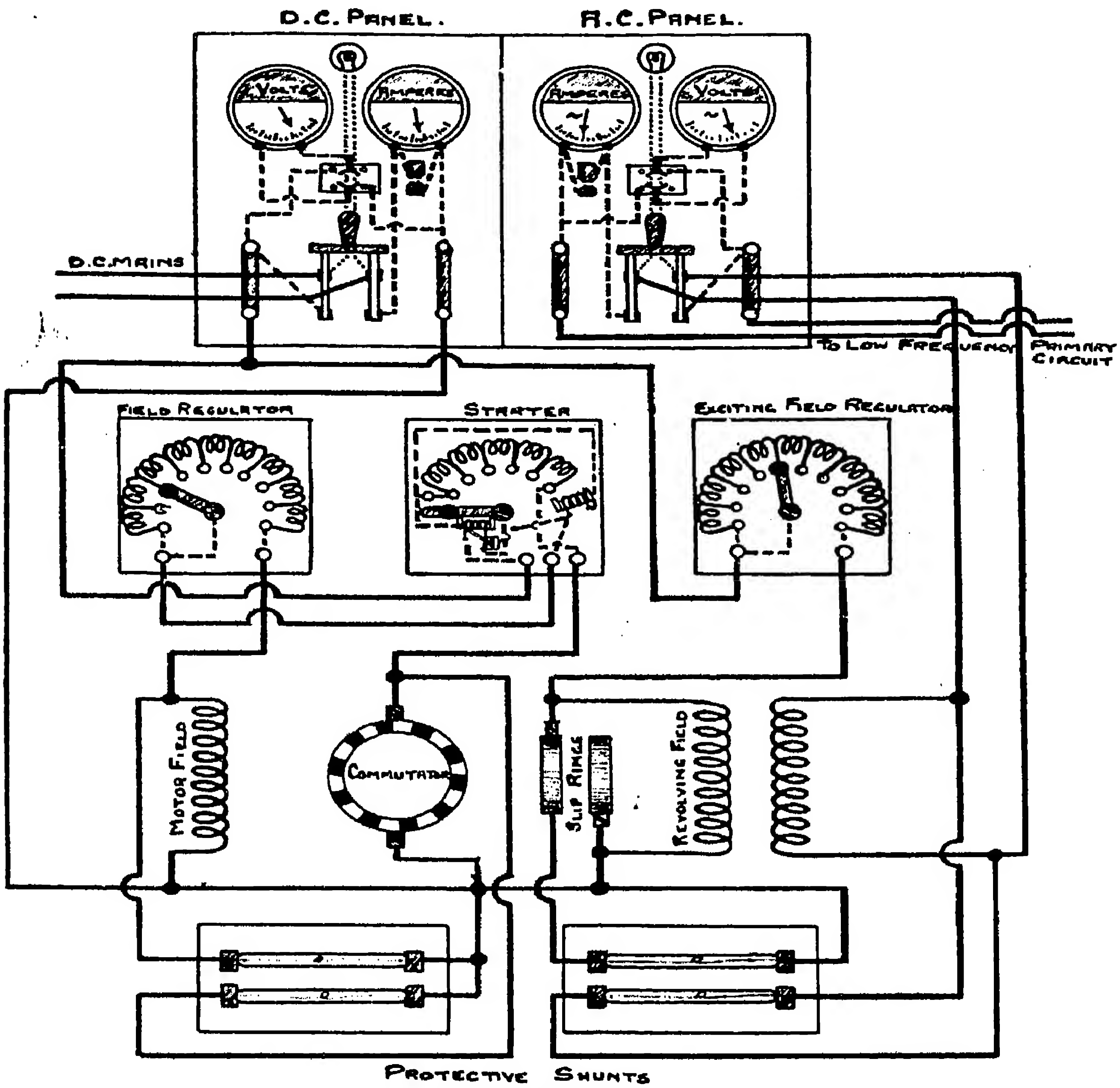

FIG. 201.—Motor-Generator Connections (5 K.W. Set).

5 *K.W. Machine Protecting Shunts.*—In place of the guard lamps used on the $1\frac{1}{2}$ k.w. set for protecting the machine armature and field, the windings of the 5 k.w. motor generator are protected by graphite sticks, which are mounted on base-boards fitted with spring clips of the type shown in Fig. 202. G is the graphite stick, fitting between the bent upper ends of the brass springs, S.

LOW FREQUENCY PRIMARY CIRCUIT.—The pieces of

apparatus in this circuit differing from the 1½ k.w. set, are the iron core inductance, the magnetic key, and the transformer.

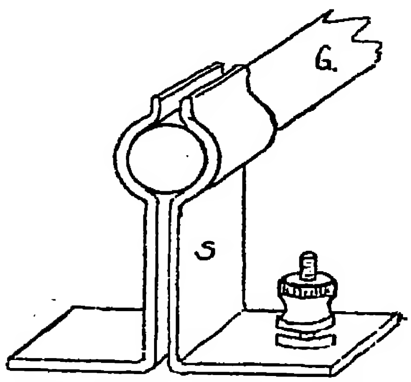

FIG. 202.—Standard for Graphite Stick.

The Iron Core Inductance is only different in that it is of greater inductive range, from 0 to ·19 henry, and that the adjustment is made by means of a brass spring brush with insulating handle moving over a series of brass stops.

The Double Magnetic Relay Key.—The primary alternating current delivered from the motor-generator, is at a pressure of anything between 100 and 300 volts, and a shock from such a source would be very unpleasant to the operator. By using a double magnetic relay key, it is possible to work the manipulating key on a low voltage. A direct current of low voltage, or of the same voltage as supplied to the motor, is passed through the latter and through one pair of coils in the former, thus working an armature which closes the alternating-current low-frequency primary circuit. Fig. 203

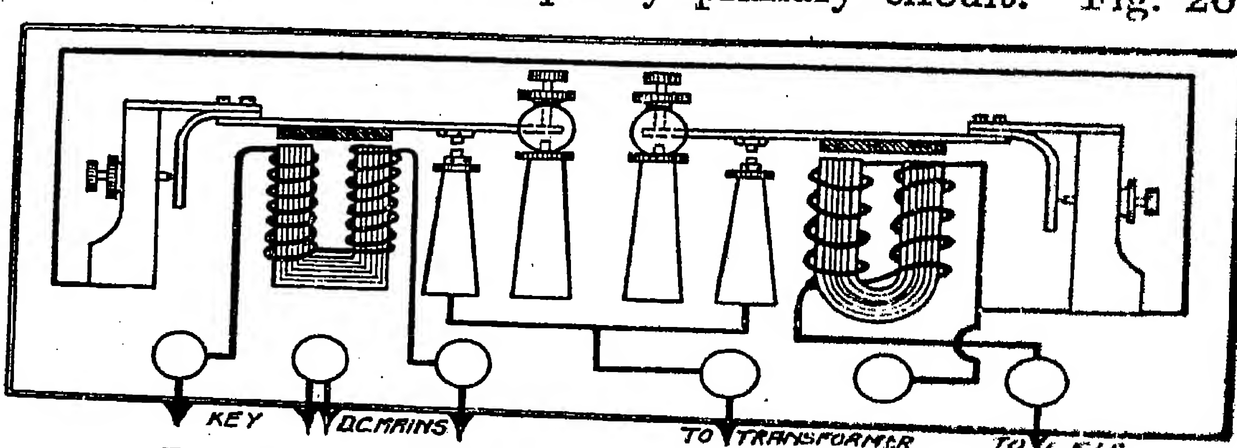

FIG. 203.—Double Magnetic Relay Key (5 K.W. Set).

shows the connections of the double magnetic relay key and requires no further explanation. The windings of the D.C. coils are of much finer wire and of greater number of turns than those of the A.C. coils, as the current used is so much smaller.

The Transformer.—This consists of an iron-core transformer with a single primary winding and a secondary divided into two parts. It is contained in an oil-tight galvanised steel tank, which is filled with high-flash insulating oil. The two ends of the primary are brought through heavy ebonite

or porcelain bushes to one side of the container, the four ends of the divided secondary being similarly brought to the opposite side. The secondary terminals are fitted with two brass straps, by means of which the two parts may readily be connected either in series or parallel. Fig. 204 shows how these connections are made. The two brass straps are connected between B and C for the series arrangement and between A—B and C—D for parallel. The transformer is capable of delivering 5 kilo-volt-ampères at either 10,000 or

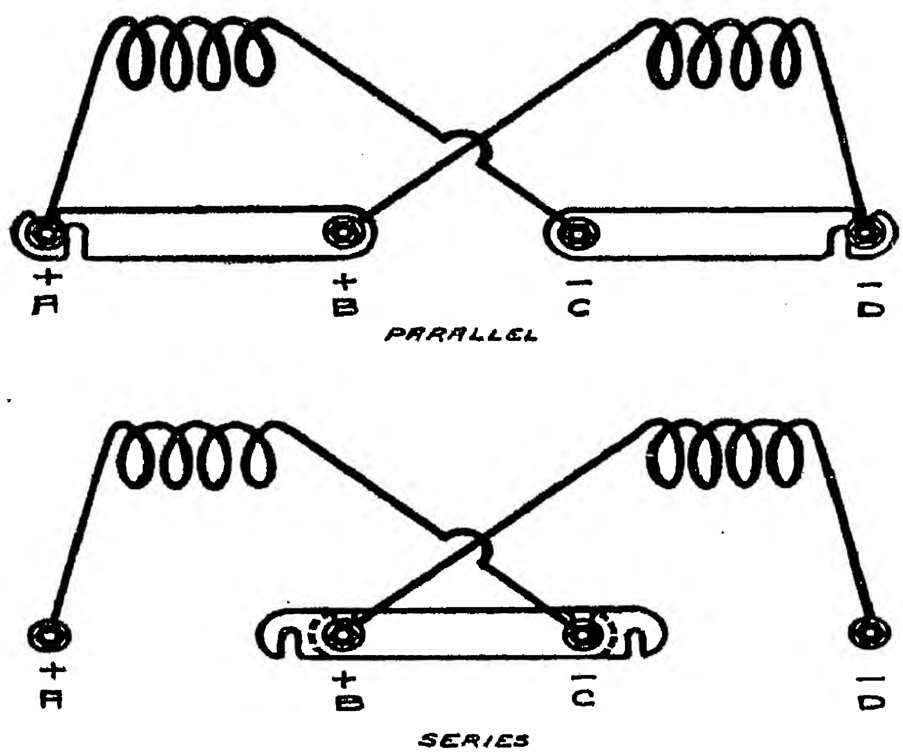

FIG. 204.—Transformer Secondary Connections, 5 K.W. Set.

20,000 volts when supplied with alternating current at 300 volts and 70 cycles.

THE HIGH TENSION CIRCUIT.—The main difference from the 1½ k.w. circuit is that the choke coils are much larger as the windings have to carry a heavier current, and they have also to choke back longer waves. The condenser will be considered in the closed oscillatory circuit.

THE CLOSED OSCILLATORY CIRCUIT.—*The Main Condenser.* —The complete condenser bank can be varied over a wider range of capacity than is possible in the smaller power sets. It consists of four units which are mounted on two teak stands having porcelain feet.

A wooden framework is erected round the bank in such a

manner that a controlling device may be placed immediately above the condensers, by means of which, different parallel, or series, or series-parallel arrangements of the separate units may easily be effected. Each unit is made up of 36 glass plates having twice the area of the 1½ k.w. condenser plates,

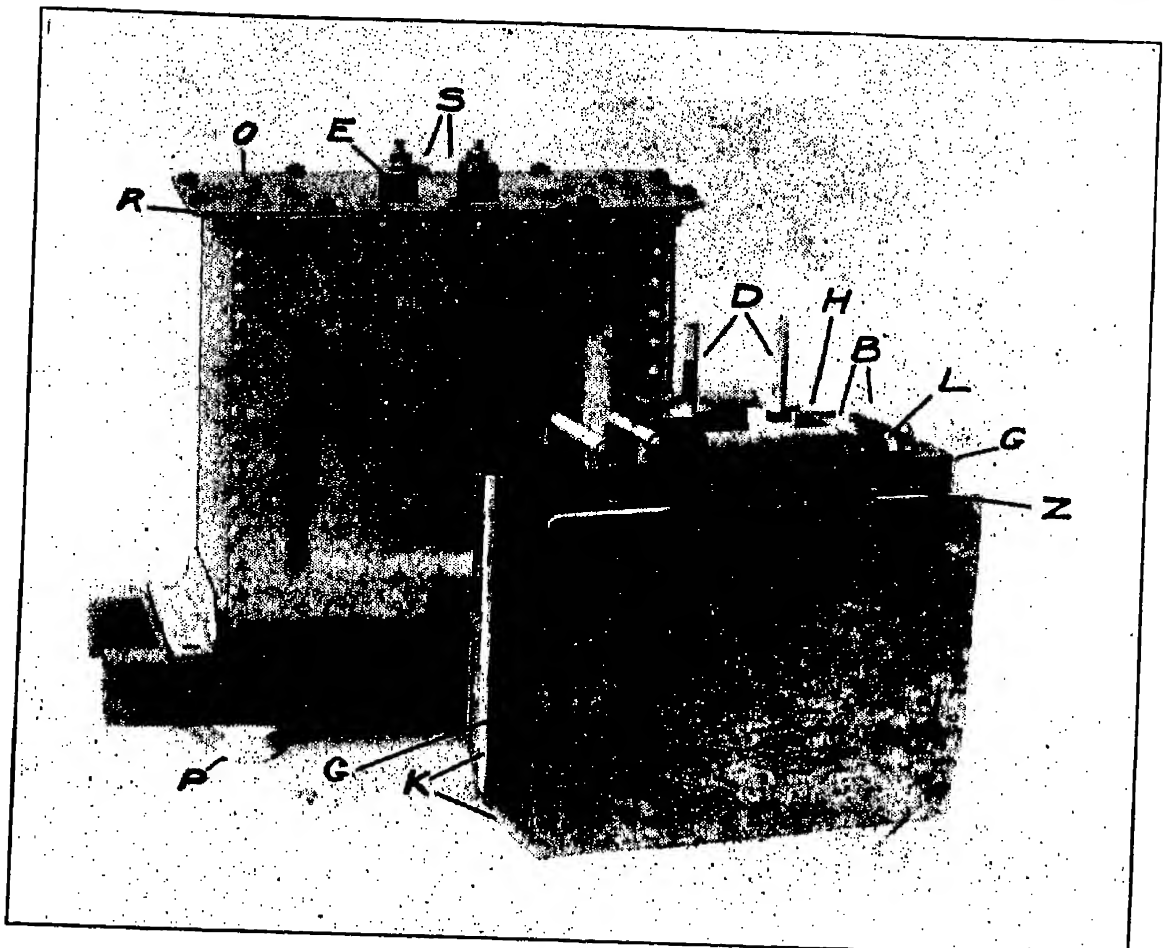

FIG. 205.—THE DOUBLE PLATE, WHOLE PLATE CONDENSER.

A, Tank Stand.—B, Brass Lug Washers.—C, Galvanised Iron Cradle.—D, Terminal Bolts.—E, Ebonite Bushed Terminals.—G, Glass Plates.—H, Copper Connecting Strip.—K, Oiled Wood and Cork Packing.—L, Leather Stools.—O, Oil-filling Hole.—P, Porcelain Feet.—R, Rubber Packing.—S, Spark Guard Points.—T, Galvanised Tank.—Z, Zinc Sheets.

interleaved with 17 zinc sheets, two glass plates between each pair of zincs (see Fig. 205).

The complete assembly of plates is supported in a galvanised iron cradle, and is contained in a galvanised iron tank packed with sheet and block cork, and finally filled with high-flash insulating oil to prevent brushing. The unit is described as a "double plate, whole plate condenser," and has an average capacity of ·016 mfd.

The Swiss Commutator.—The condenser controlling device is called a Swiss Commutator and is shown in Fig. 206. A and B are hollow copper bars of square cross-section, each drilled through with five holes. They are supported in a horizontal

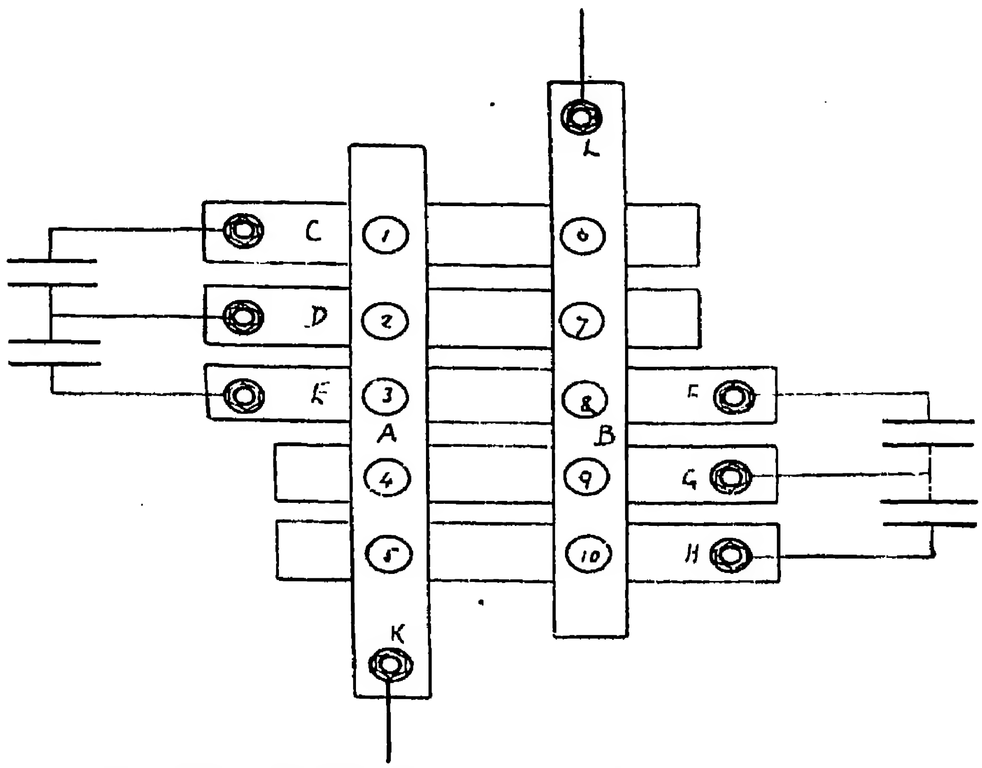

FIG. 206.—Swiss Commutator for 4 Condensers.

position on two ebonite standards, fixed on a baseboard which carries five other bars of similar cross-section, placed horizontally with their axes at right angles to A and B and about two inches below them. The lower bars have terminal screws at the points marked C, D, E, F, G, H, and it will be seen that the central one has terminals at each end. The four condensers are connected to these terminals as shown. The terminals L and K of the upper bars are connected to the leads from the air core chokes and also to the rest of the closed oscillatory circuit. Split brass plugs of the shape shown in Fig. 207 are used to connect the upper to the lower bars. If two of these plugs be fitted through the holes marked 1 and 10 into the corresponding holes beneath, it is seen that the four condensers are joined in series. If plugs be placed through the holes marked 1, 7, 3, 9, and 5, or through the holes marked

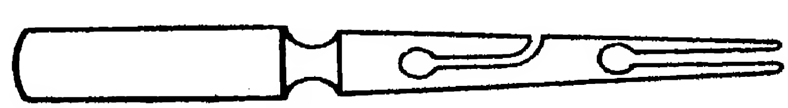

FIG. 207.—Plug for Swiss Commutator.

6, 2, 8, 4, and 10, the four condensers will be connected in parallel. If plugs be placed through the holes marked 6, 3, and 10, the condensers will be arranged in two groups of two in series, the two groups being connected to the circuit in parallel.

The connections between the condensers and the commutator are made with stout copper strip of ample surface, and ebonite strips are placed between the bars of the commutator, and between the copper connecting strips to prevent sparking. Spark points of flat brass are fitted to the condenser terminals, and set so that any excessive voltage will break down the air resistance between them in preference to breaking down the condenser.

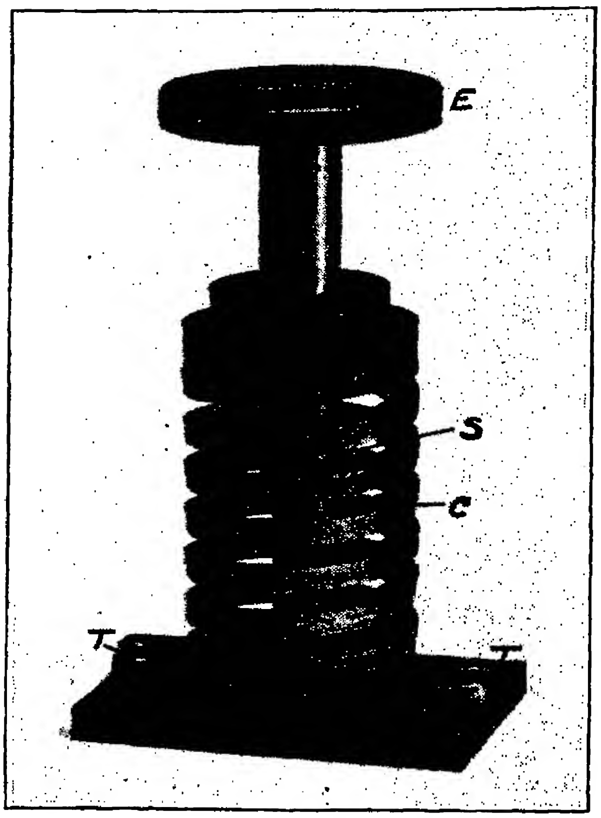

FIG. 208.—HIGH FREQUENCY SPIRAL INDUCTANCE (5 K.W.). Type No. 1.
C, Heavy Copper Spiral.—E, Ebonite Adjusting Handle.—S, Spring Brush.—T, Terminals.

High-frequency Inductance.—A high-frequency inductance, Fig. 208, consisting of a heavy copper spiral of square cross section, takes the place of the sliding inductance used in the 1½ k.w. set. A brass tube, working on a thread cut in the central brass spindle, which has the same pitch as the spiral, carries a spring brush which makes contact on the inner surface of the spiral, and travels up it when the ebonite handle of the tube is rotated. The amount of spiral in circuit,—and therefore the amount of H.F. inductance,—can thus be regulated.

The Transmitting Jigger.—The 5 k.w. Plain Discharger Set was originally designed for use on board ship. Its working range of wave lengths was therefore limited to 300 metres and 600 metres, but the actual range obtainable, using a jigger similar to the one on the 1½ k.w. set, is from about 250 metres to 1100 metres.

THE OPEN OSCILLATORY OR RADIATING CIRCUIT.—This in-

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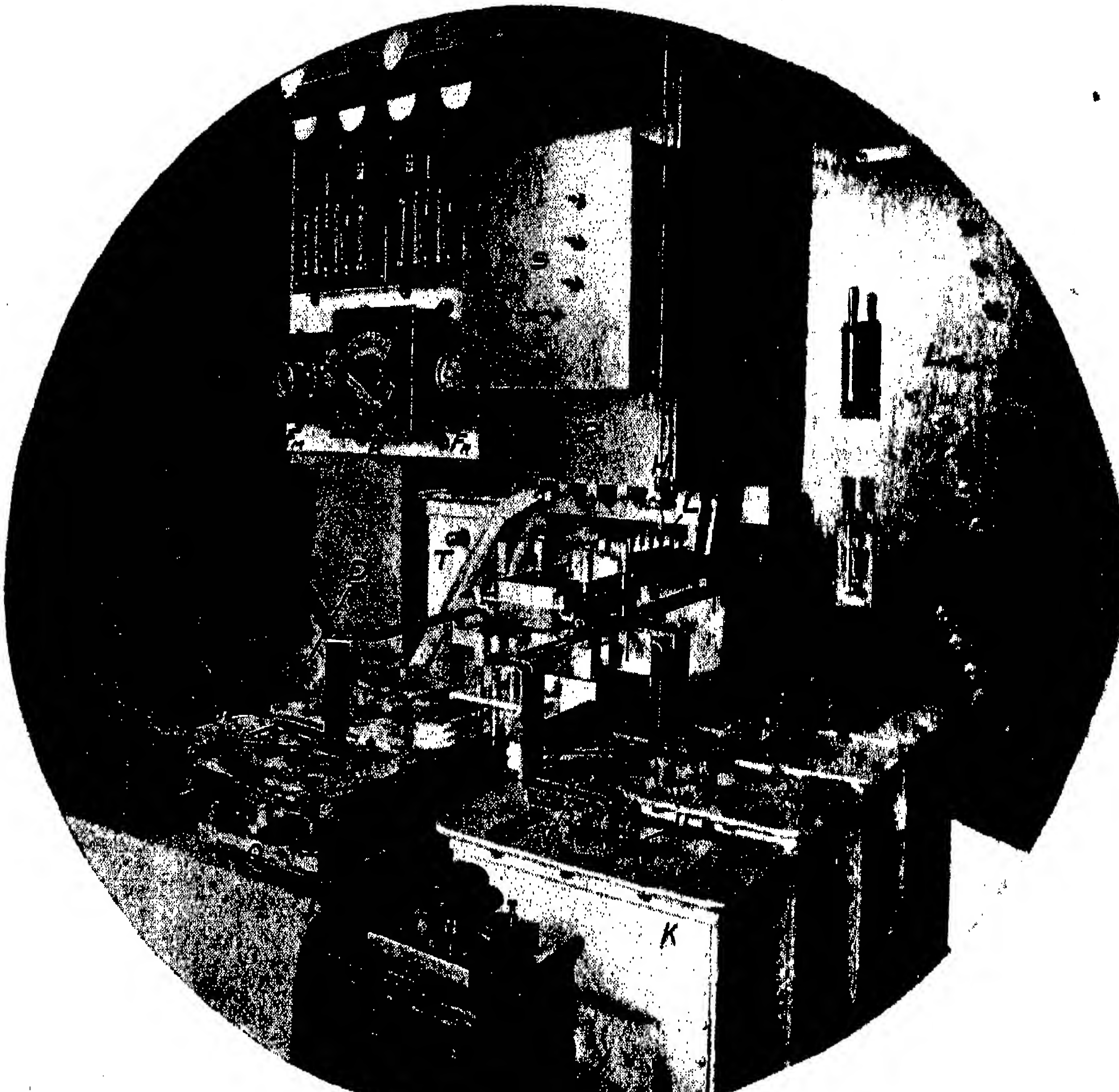

FIG. 211.—THE 5 K.W. "BATTLESHIP" SET.

B, Discharger Box.—C, Rubber Insulating Coupling.—D, Disc Discharger with Transverse Studs.—E, Ebonite Separators.—FA, Alternator Field Regulator.—FM, Motor Field Regulator.—H, Jigger Screw Coupling Adjustment.—K, Condenser Tanks.—LA, Aerial Tuning Inductance, Large Unit.—LB, Aerial Tuning Inductance, Small Unit.—LH, Spiral Inductance, High Frequency.—LL, Primary Inductance, Low Frequency.—M, Motor of Motor Alternator Set.—O, Double Magnetic Key.—P, Jigger Primary Box.—Q, Manipulating Key.—R, Starter.—S, Jigger Secondary Box.—T, Transformer.—U, Condenser Terminals, ebonite bushed.—V, Copper Busbars.—W, Switchboard.—X, Swiss Commutator.

[To face p. 249.

cludes the jigger secondary, the aerial tuning inductance, the earth terminal arrester, and the earth connection,—all of which are the same as for the 1½ k.w. set—the leading-in insulator, and the aerial. For long waves one or more extra aerial tuning inductance units are provided. The 5 k.w. aerial leading-in insulator, Fig. 209, known technically as "Bradfield No. 2," is similar in design to the leading-in insulator shown in Figs. 181 and 182, but the ebonite tube is much thicker especially at the gland. The gland in consequence is large in proportion.

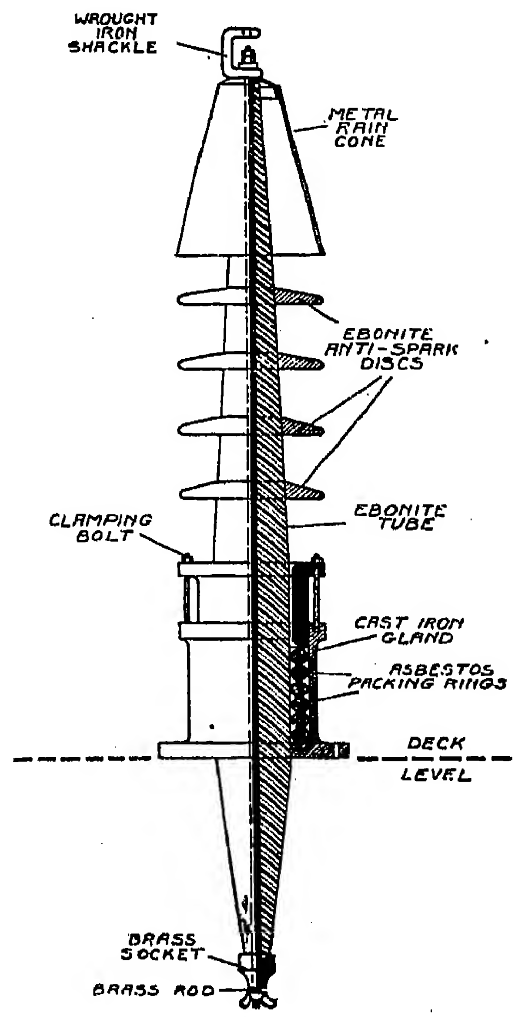

FIG. 209.—"BRADFIELD" LEADING-IN INSULATOR. No. 2.

The aerial generally consists of four wires of 7/19 silicon bronze, supported between two 20-feet spreaders (Fig. 210), the down part of the aerial being taken either from the middle or from one end, in the usual way, to the cabin leading-in insulator.

THE 5 K.W. "BATTLESHIP" SET.—This set, which is shown in Fig. 211, differs from the one just described in being adjustable over a very wide range of wave lengths, from about 400 metres to 4500 metres, by altering the connections of the condenser bank—which consists of eight whole-plate units instead of four—and the connections to the jigger primary, which now has four turns with a tapping at each turn.

The middle range only is on full power. The L.F. tuning inductance is similar in design to the inductance of the Plain Discharger set, but its range is less, from 0 to ·05 henry. The special parts which require to be separately referred to are: "The Main Condenser," "The Swiss Commutator," "The Disc Discharger," "The Transmitting Jigger," and "The Aerial Tuning Inductance."

The Main Condenser.—In outside appearance the eight condenser units are similar to the units of the Plain Discharger

Set, with the exception that as they are built to stand a lower voltage, the ebonite insulating bushes of the terminals fitted on the lid are half an inch shorter. They are known as "whole plate, single plate," condensers. They contain 36 glass plates as before, but there is only one sheet of glass between each pair of zincs, the total number of zincs being 35. The terminals are stamped 17 and 18 accordingly. The condenser, therefore, has roughly four times the dielectric capacity

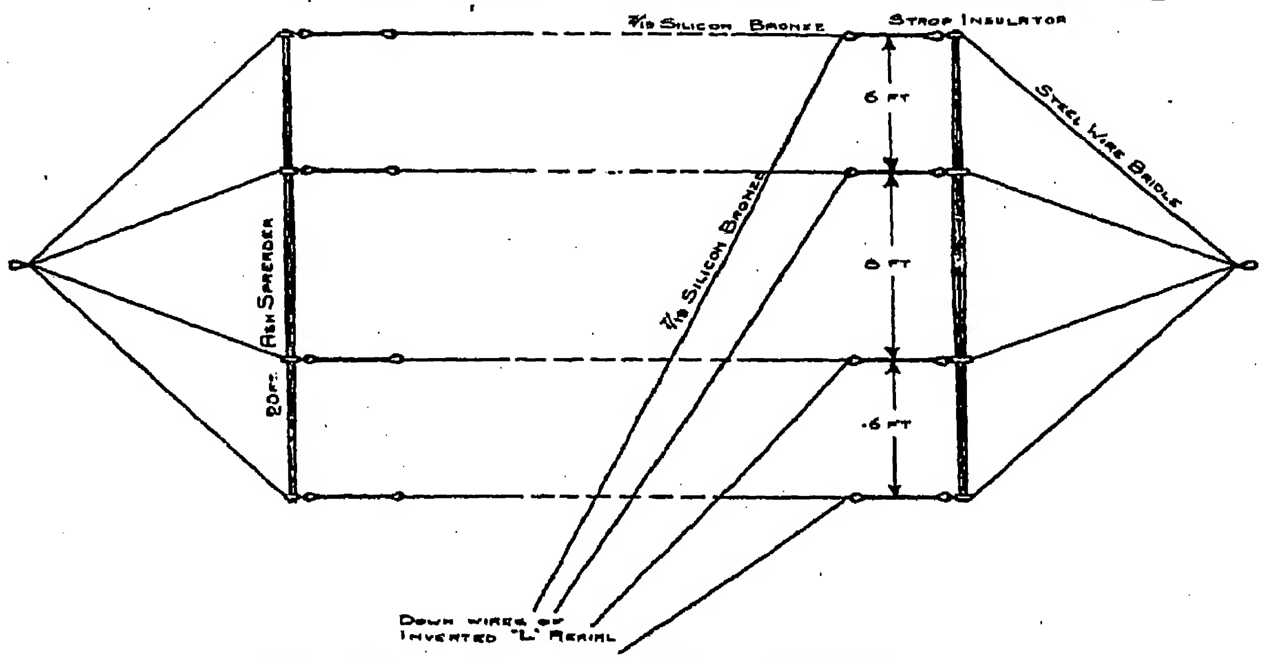

FIG. 210.—Four-wire Aerial 5 K.W. Type.

—about ·07 mfd.—but it will only stand half the working voltage, and as the power it will take depends on the product "dielectric capacity × voltage²," it will be seen that this value has not been altered. The maximum working power capacity of one of these tank condensers is 2 k.w., but they are seldom required to work on more than 1 k.w.

The Swiss Commutator.—The 4-cell commutator already described, is duplicated to make an 8-cell arrangement, but with the difference that the lower plug bars of each 4-cell half, are so arranged, that all the condensers connect to the outside ends, one lower plug bar is common to the two halves, and the top transverse bars are so mounted that the corresponding bars of each half can be conveniently joined by copper connecting strips (see Fig. 212).

The main terminals are placed on one inner and one outer bar at A and B.

By inserting plugs through the holes marked 1 and 20, the eight condensers are placed in series; while the insertion

of a third plug through the hole marked 15 and the transference of the plug in 20 to 10, gives a series-parallel arrangement with four in each series. If plugs be placed through the holes marked 1, 12, 3, 14, 5, 17, 8, 19 and 10, the eight condensers are in parallel. Finally, if plugs be inserted in the holes marked 1, 13, 5, 18 and 10, the resulting condenser arrangement is two series four parallel.

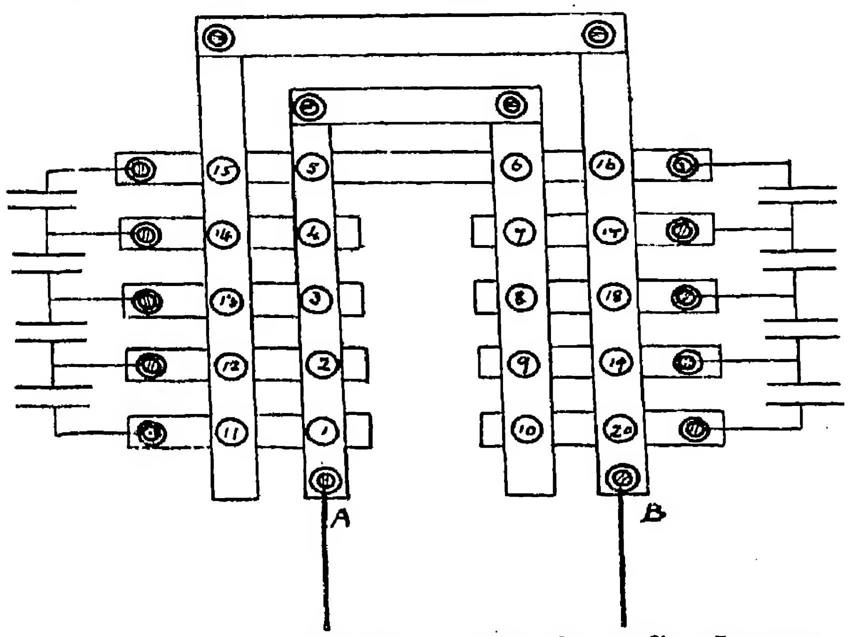

FIG. 212.—Swiss Commutator for 8 Condensers.

The Disc Discharger.—The disc discharger was developed originally at the Marconi high power stations, as by its means it was possible to handle much more power in the transmitting circuit, and to reduce very considerably the spark losses. When the transmitting circuit is in proper adjustment, the condenser spark discharge at the disc takes place at absolutely regular intervals, and if the sparks are frequent enough they produce a musical note.

There is no note with a fixed discharger as the spark is irregular in character, and it has a constant tendency to arc.

The great advantage of a musical note resulted at a later date in the introduction of the disc discharger in small power sets, and the first type of small power disc discharger to be employed was the one now to be described. It retains, as one would expect, several features of the high-power disc.

A high-power disc, owing to its diameter and speed, must be completely of metal to be run with safety. It would fly to pieces if it consisted of a studded metal rim mounted round a disc of insulating material, which is quite sufficient and safe

for a small power disc. Its insulation from the driving motor must be arranged in a different manner. High-power discs also use transverse studs instead of radial studs, as the difficulties of safely holding them when the disc is travelling at a high speed, and also of mounting the rotary electrodes, are in this way much less.

The "Battleship" type discharger, then, consists of a circular steel plate 10 inches in diameter, fitted near its periphery with 16 equally spaced transverse copper studs. Sometimes only 4, or 8, are used, depending on the arrangement

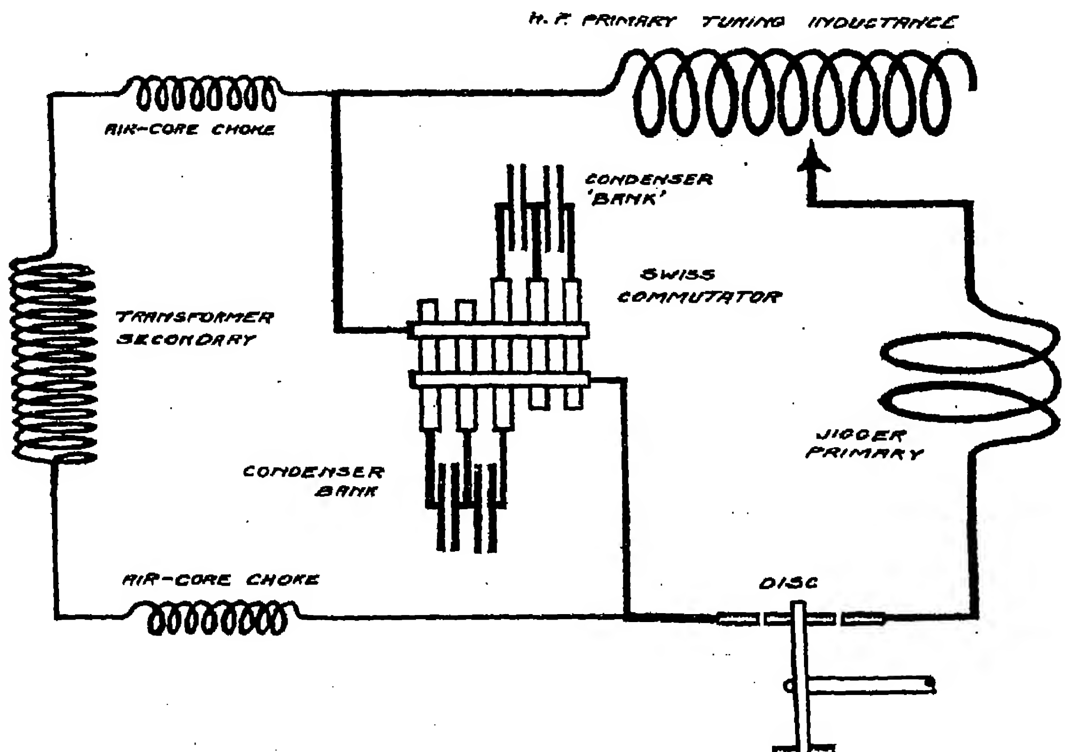

FIG. 213.—5 K.W. Closed Oscillatory Circuit with Disc, together with Charging Circuit.

of the rest of the circuit. These studs project 1 inch from either face and take the spark from two fixed copper electrodes between which the disc revolves. The disc has an independent shaft running in ball bearings, which is direct coupled to the motor generator shaft through an insulating rubber coupling, and is enclosed together with the electrodes in a heavy teak box designed to deaden the noise of the discharge.

Heavy ebonite handles project through two sides of the box, by means of which the ebonite pillars holding the electrodes may be moved towards or away from the disc, in order to adjust the length of the sparking gaps.

To allow for this movement, the inside connections between

the main terminals passing through the box, and the electrodes, are made with heavy flexible cable. The main terminals are connected to the closed oscillatory circuit in the same way that the ordinary fixed discharger terminals are connected. Fig. 213 shows the general arrangement of the charging and H.F. primary circuit

The disc discharger is generally adjusted so that a spark takes place at each half period. If the voltage be a little lower at the end of one half-period than at the end of another, the spark takes place when the moving electrode has approached a little nearer the fixed ones, and *vice versâ*, but on account of the constant speed of rotation, and the variation in distance likely to occur being very small, the slight delay or advance of the discharge has little effect in spoiling the purity of the note.

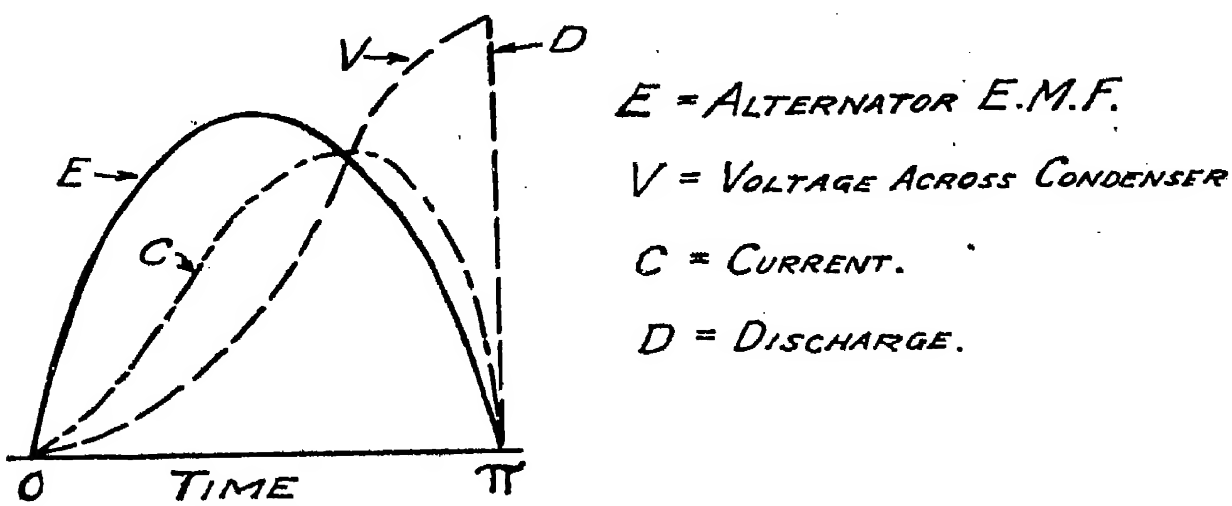

FIG. 214.—Condenser Charging Curves.

Fig. 214 shows the curves of alternating E.M.F., current, and condenser voltage for one half-period, when the charging circuit—which consists of alternator, low frequency tuning inductance, transformer, and condenser,—has a natural frequency equal to the frequency imposed on the circuit by the rotational speed of the alternator, and the number of times the field is reversed through its windings per revolution. (See paragraph on Resonance, p. 101.)

The discharge is shown taking place when the A.C. voltage is at zero value, at which instant the tendency to arc is a minimum.

The first spark of a train jumps from the electrode towards the advancing stud, but as the discharge proceeds and the stud rapidly approaches nearer to the electrode, the spark resistance loss due to length of gap decreases, which is another advantage the disc discharger has over the fixed discharger. The change in gap resistance, however, does not follow a

straight line law. It is quite appreciable when the gaps are big, but there is very little difference when the gaps are small.

Because the spark must take place at a fixed time with respect to the voltage of the alternator, and because the relationship varies for different arrangements of condenser, it is necessary to provide a spark phase adjustment. There are two quadrant slots in the half-coupling on the disc shaft for this purpose. The studs which drive the disc pass through these slots and can be clamped tight at any position in them. The disc half-coupling can therefore be set at any position within a quadrant relative to the half-coupling on the alternator shaft.

By this means the relative angular position of the disc studs and the alternator magnet poles can be controlled, which makes it possible to set the disc so that a moving stud comes exactly between the fixed electrodes at that instant of lag or lead on the alternator E.M.F. found best by trial.

The spark phase displacement is shown by an index mark on the rim of the disc half-coupling, and a scale of phase degrees on the rim of the stud plate.

When the index mark is set at 0° on the scale, the discharge will take place at the moment of maximum volts on the alternator; at 10° lag the discharge will take place at a point on the voltage curve 10° of phase after the maximum voltage has been reached, and so on.

It must not be forgotten that the spark frequency has nothing to do with the oscillation frequency, the latter depending merely on the oscillation constant of the circuit, while the former depends on the speed of the disc and the number of studs employed. Thus, if the disc carrying sixteen studs rotates at a speed of 2100 revolutions per minute, there will be 33,600 sparks per minute, or 560 per second, which is the value of the spark note.

The Transmitting Jigger.—The primary is wound with four turns of heavy stranded cable, tapped at the end of each turn. The ebonite end plate of the box, supports the five solid brass tapping lugs, and behind them runs an insulated horizontal copper bar on to which either one or other of the lugs can be plug connected. This primary gives an adjustment of inductance in steps from ·8 mhy. to 12 mhys.

The secondary winding consists of the standard seven turns.

Instead of the slotted brass plates on the sides of the secondary box, with thumb screws through the slots for

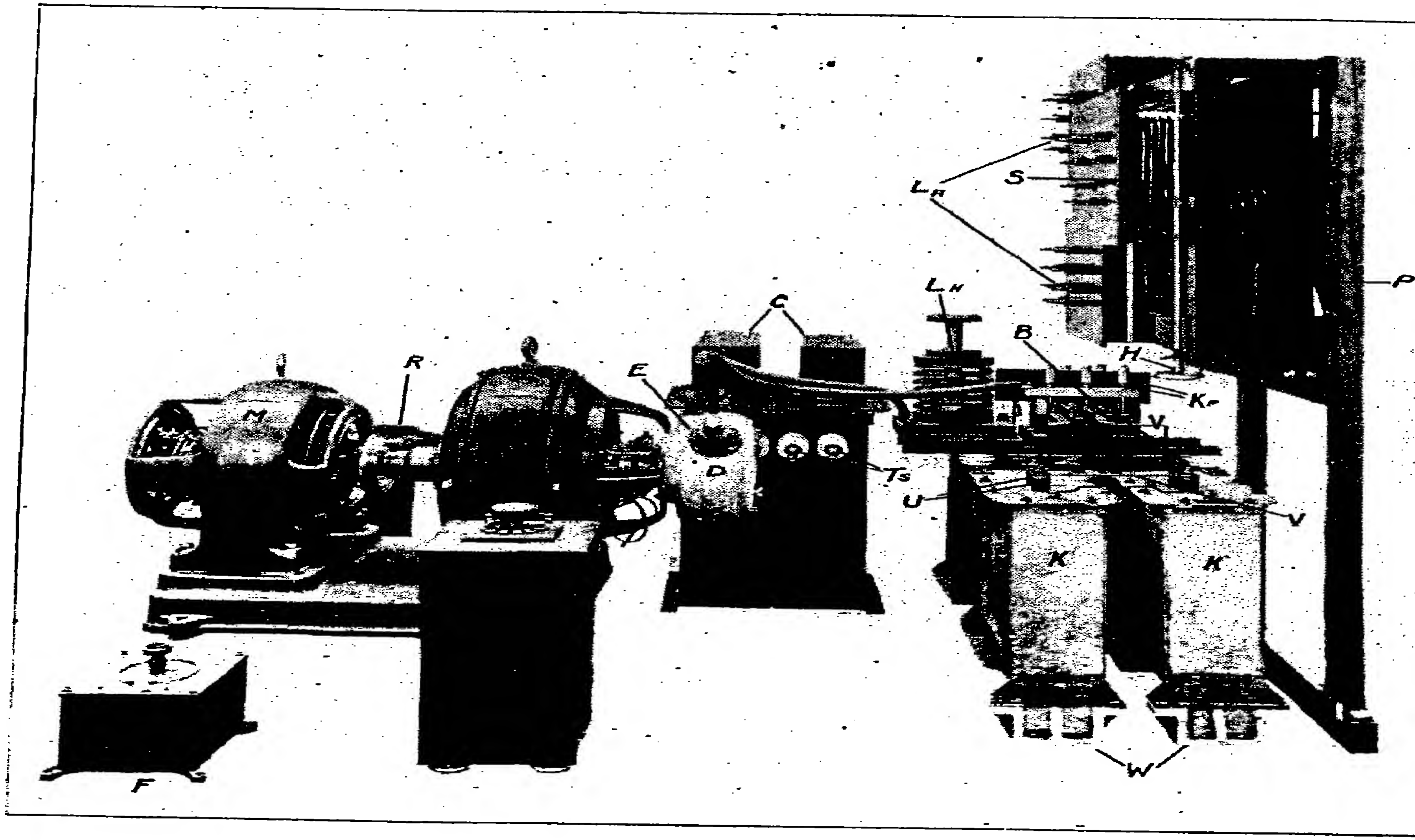

FIG. 215.—THE 5 K.W. "SPECIAL" SET.

A, Alternator.—B, Swiss Commutator.—C, Air Core Choke.—D, Disc Discharger, overhung type.—E, Disc Electrode, Terminals.—F, Field Regulator.—H, Handle of Coupling Adjusting Screw.—J, Skeleton Transmitting Jigger.—K, Tank Condenser Unit.—KP, Condenser Plugs.—LA, Aerial Tuning Inductance.—LH, H.F. Primary Tuning Inductance, No. 2 Spiral.—LL, L.F. Primary Tuning Inductance.—M, Motor.—P, Jigger Primary.—R, Starter.—S, Jigger Secondary.—T, Transformer.—Ts, Transformer Secondary Terminals.—W, Porcelain Condenser Tank Supports.

clamping the box in a given position over the primary winding to obtain a certain coupling, the coupling is adjusted by means of a handle and screw fitting.

The Aerial Tuning Inductance.—This is split up into two units, one for rough adjustment having a total value of 550 mhys., and a plug socket tapping every 50 mhys., the other for fine adjustment having a total value of 50 mhys., and a plug socket tapping every 2 mhys. The large unit is subdivided into three sections, which are connected by knife switches. In order to minimise the potential strains on the apparatus, the aerial should always be connected to the top socket and inductance should be added downwards. Also the section of the large inductance not in use should be disconnected.

THE 5 K.W. "SPECIAL" SET.—The latest design of 5 k.w. disc set, which is illustrated in Fig. 215, covers a range of transmitting wave-lengths of 300 metres to 1000 metres, 1200 metres, 1800 metres, or 2500 metres, as may be required, and introduces several improvements.

An alternator frequency of 70 cycles gives a low synchronous note which does not aid reception very much by its pitch when signals have to be read through atmospherics. As with the 1½ k.w. set, a higher note could be obtained from a 70 cycle supply by using an *asynchronous* disc, but the note would not be pure in tone, and the electrical efficiency—alternator output to aerial input—would be less.

The tendency, therefore, has been to increase the frequency of the alternator supply, and thus put up the pitch of the *synchronous* note. A spark frequency of from 400 to 700 per second, one spark per half cycle, appears to give best results. Operators complain that the ear gets tired if it has to listen continuously to notes of too high a pitch.

The alternator of the special 5 k.w. set delivers its supply at 500 volts 300 cycles.

The Single Magnetic Relay Key.—The action of the magnetic key as described on p. 148 is to open the main circuit—not necessarily at the instant at which the manipulating key tends to open it, but at a small fraction of time afterwards—when the alternating current will be at its zero value, and when therefore there will be no arc, so as to reduce the wear on the contacts and to increase the speed of operating.

The principle on which it works, is, that the flux in the key electromagnet follows the fluctuations of the alternator main

current, and thus causes the armature arm carrying one of the main contacts to vibrate at twice the frequency of the alternator supply. The magnetic key main contacts then open every time the current falls to zero, twice every cycle, and if the manipulating key contacts are open at the same time, the main circuit is broken.

There are certain limitations to the use of this key. The natural period of the vibrating arm is controlled by the tension of a strip spring. The arm vibrates between two stops. Its natural period is therefore strongly damped, but at the same time its influence is felt, and for best results it should be made considerably greater than that of the alternator frequency. This is not so easy to arrange if the alternator frequency has

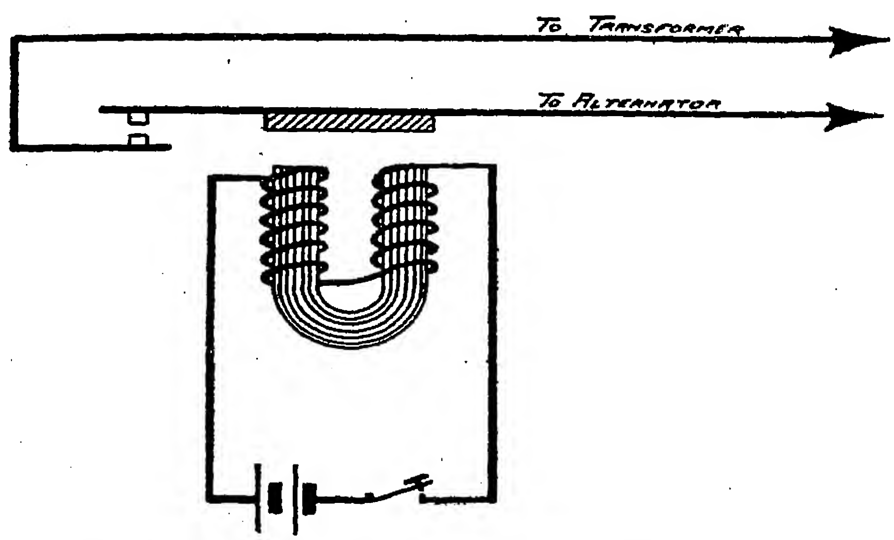

FIG. 216.—The Single Magnetic Relay Key.

a value of 300 cycles, or if the alternator voltage is 500 volts, as high voltage requires a wider gap at the contacts. Again, this heavily damped quick vibration generates a large amount of heat, and more heat is generated in the armature and magnet core by hysteresis and eddy current losses, which are considerable at such a frequency even when the iron is finely laminated.

These are the reasons which make it preferable to use another type of magnetic key on the special 5 k.w. set. In appearance it is very similar to the single magnetic key used on the 1½ k.w. set, Fig. 111, but its internal connections, as shown in Fig. 216, are different. Only the contacts are in the main A.C. circuit; the winding is in a separate control circuit run off the D.C. supply.

The Low Frequency Tuning Inductance.—There are two types in use. One, which is inserted in the transformer

primary circuit, LL in Fig. 215, the other, which is used as an alternative and is inserted in the transformer secondary circuit, illustrated in Fig. 217.

The primary circuit inductance consists of a winding on an open iron core, having a number of tapping connections brought to the brass contact studs of a regulator. The coil is enclosed in a ventilated teak box mounted on porcelain feet. It has a maximum value of ·05 hry. or ·02 hry. depending on the electrical constants of the rest of the circuit, and is adjustable in eight steps. Such an inductance is compact, and quick and easy to manipulate. Its electrical efficiency, however, is not quite so high as that of the air core secondary inductance.

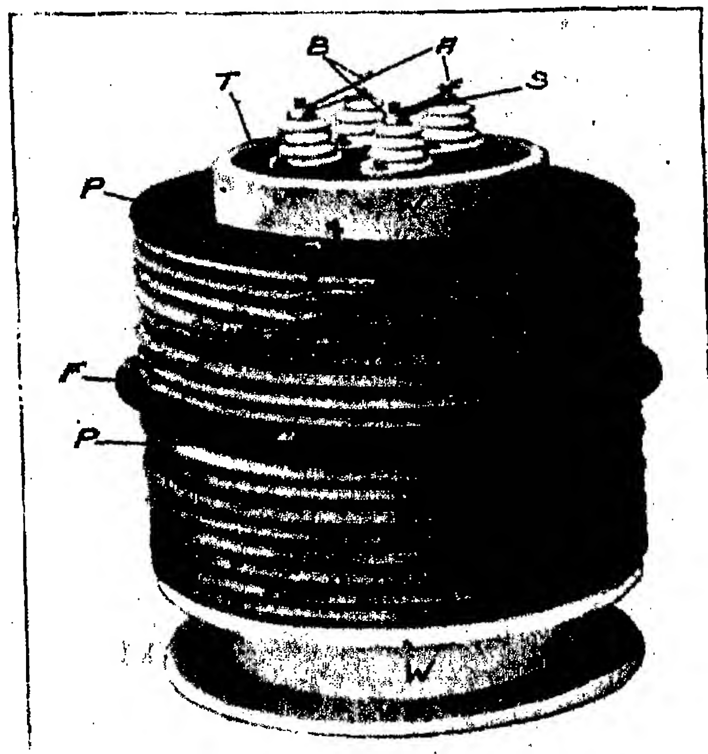

FIG. 217.—L.F. SECONDARY TUNING INDUCTANCE, 5 K.W.

A, Terminals of Section "A."—B, Terminals of Section "B."—F, Fibre Ring.—P, Protector Sub-section.—S, Straps for Cross Connections.—T, Teak Plate.—W, Ironstone Former.

The secondary inductance is supplied in two units which are connected one in each high tension main, between the transformer secondary terminal and the air core choke. Each unit is mounted on an ironstone former and is divided into two parts marked A and B respectively, and having a total inductance per part of 2·45 hrys., which can be connected either in series or parallel to agree with the arrangement of the transmitting condensers, by means of brass straps fitted to porcelain bushed terminals on the wood plugged top.

Each part is divided into eight main sections, and one sub-section of fewer turns and higher insulation which acts as a high frequency protector to the other eight.

The Air Core Protector Chokes.—The wood boxed chokes marked C in Fig. 215 are most generally replaced by pile-

wound chokes on porcelain formers like the one illustrated in Fig. 130, or single-layer chokes on porcelain or ironstone formers as shown in Fig. 218. In either case the natural period of the choke must considerably exceed the period of the longest wave transmitted by the set, which may be anything from 1000 metres to 2500 metres according to requirements. A single-layer choke is the best protector, but it takes up much more space and costs more than a pile-wound choke having the same natural period. The capacity of the pile winding, however, tends to allow very short waves to leak through it from layer to layer, but the longest wave which could do this would be very much smaller than the shortest wave produced by the transmitting set, so that the capacity of the winding is no real disadvantage.

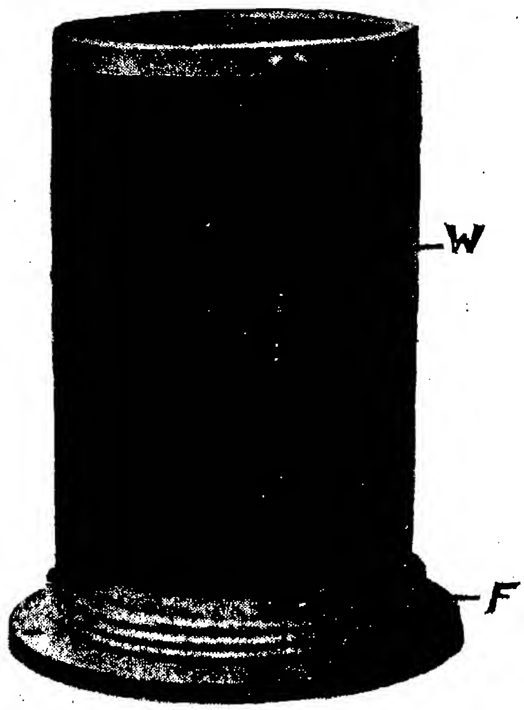

FIG. 218.—AIR CORE PROTECTOR CHOKE, 5 K.W. AND UPWARDS.
F, Ironstone Former.—W, Enamelled Wire.

The Condenser Bank.—This is a return to the four-cell arrangement used in the Plain Discharger set, each unit having a capacity of approximately ·016 mfd. Occasionally this provides more capacity than the minimum wave length of the set requires. Zinc plates are then removed, an equal number from each unit, until the right adjustment is obtained. The power is maintained the same in spite of the lower capacity by increasing the alternator voltage, the design of these sets being sufficiently elastic to allow for such changes.

Fig. 215 shows an improved method of insulating the condenser bank from the ground, or steel deck of a ship as the case may be. In place of the teak stand with porcelain feet, each unit has its own two porcelain supports designed to take the full weight of the condenser, the fixing and holding-down bolts, and also to provide sufficient insulation surface to earth.

The galvanised tank condenser unit with its sealed top—a rubber washer is clamped tight between the flanged top of the case and the lid—is eminently suitable for ship work. On land,

the condenser need not be bolted down and is not subject to rough treatment; it can therefore be built on different lines.

Fig. 219 shows the direction the modification in design tends to take.

The galvanised tanks are replaced by cream glazed ironstone pots, with special foot mouldings to supply the necessary surface insulation between the bottoms of the condenser containers and the ground. The tops of the pots are expanded

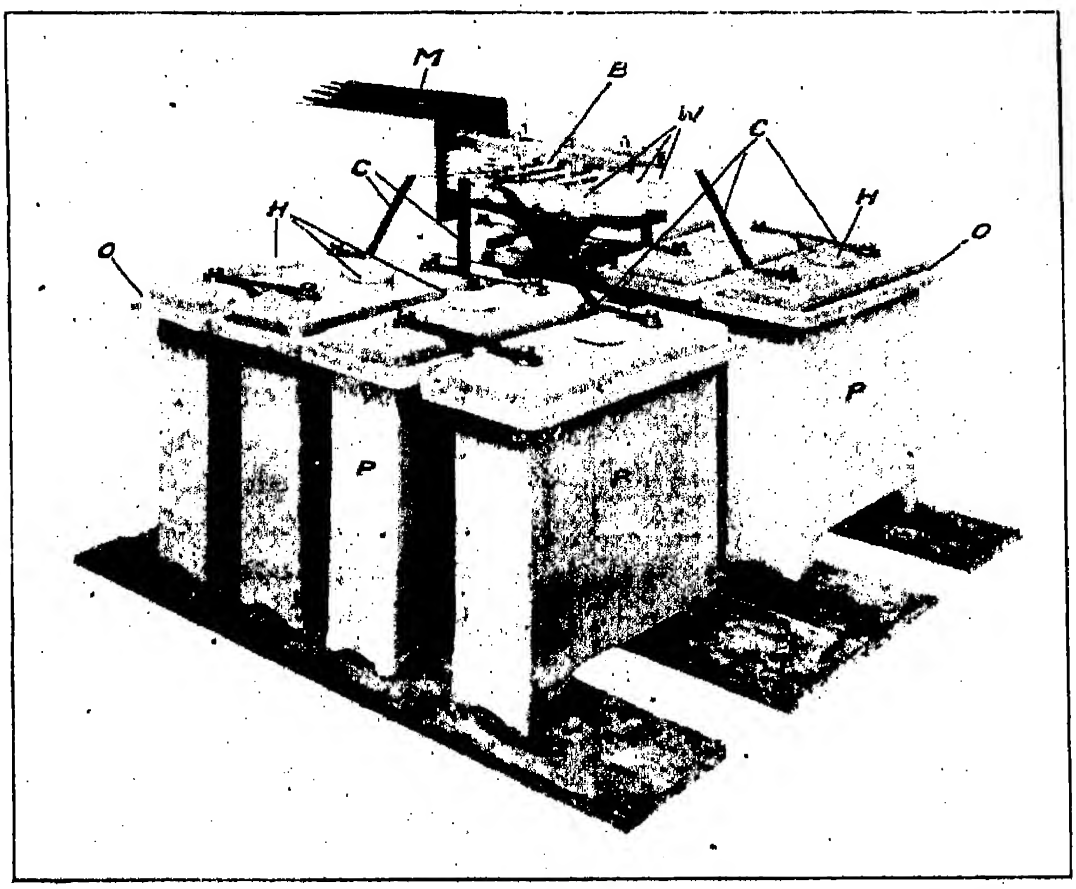

FIG. 219.—"POLDHU" POT CONDENSER BANK, 5 K.W.

B, Swiss Commutator.—C, Connectors.—H, Oil Filling Holes.—M, Main Busbars.—O, Troughed Tops for Oil Seal.—P, Ironstone Condenser Pots.—S, Cast Iron Standard.—W, Porcelain Insulators.

and channeled to hold a heavy oil, so that the edge all round each lid can rest in the channel and so oil-seal the condenser.

As each condenser can only hold 20 glass plates, two of them must be used to replace one tank unit, which holds 36 glass plates, Also, as they are always made up as single-plate condensers—that is, with one glass plate between each pair of zincs—and the tank unit has two glass plates between zincs, the two earthenware pots must be placed in series to have the same dielectric strength as the tank unit.

Thus the complete bank consists of eight units, permanently connected two in series, but capable of having three changes of capacity by means of a commutator adjustment as arranged for the tank condenser set. The full capacity of 20 plates per unit—about ·037 mfd.—is not always used. A certain number of zinc sheets may be removed from each pot if necessary, the glass plates thus rendered inactive remaining in the pots.

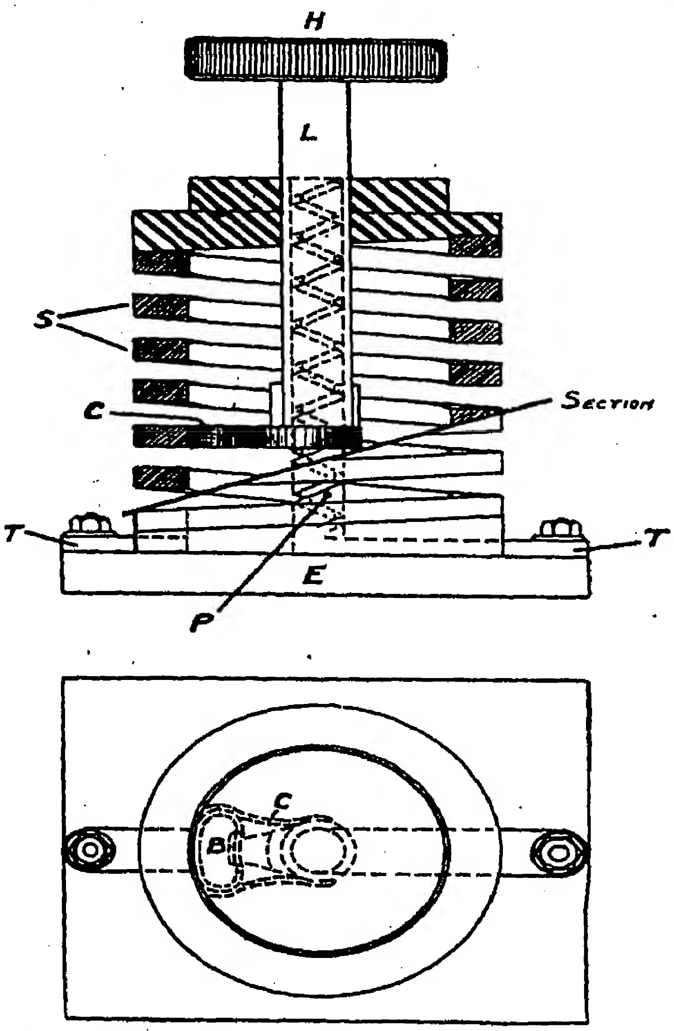

FIG. 220.—H.F. SPIRAL INDUCTANCE 5 K.W. No. 2.

B, Bronze Brush Spring.—C, Copper Braid.—E, Ebonite Base.—H, Ebonite Handle.—L, Brass Tube.—P, Screwed Brass Pillar.—S, Copper Spiral.—T, Brass Terminal Blocks.

The tank condenser unit is built up in the same way as the $1\frac{1}{2}$ k.w. condenser, and is then lifted bodily in its cradle into its container, but as no cradle is supplied with the ironstone pots, the other fittings however being standard, the pot is laid down on its broad side and the condenser is built up plate by plate in the pot.

Care should be taken to see that the glass, zinc sheets, and fittings, are thoroughly dry before assembling, the oil is free from water, and that the oil after filling is maintained at a level above the glass plates, the higher the better. Also that the oil seal is made effective.

The Swiss Commutator.—Fig. 215 shows a four-cell commutator of the type used on the plain discharger set. This is most generally used. Fig. 219 shows a commutator which can make exactly the same number and same kind of changes, but its insulation consists of air space and porcelain instead of ebonite. It costs more to manufacture, its H.F. inductance is necessarily greater owing to the increased space required for air insulation, and the accurate alignment of bars and fitting

of the plugs need very careful workmanship, but it has the advantage of being fireproof.

The High Frequency Primary Tuning Inductance.—This is a larger edition of the spiral inductance illustrated in Fig. 208, and is shown in section in Fig. 220. It has a value of about 3 mhys., which is enough to bridge the gap between the inductance of one jigger primary turn and the next. Sometimes its effective value is increased by the bend of the busbar connectors round it. This bend may oppose the spiral instead of assisting it, if the busbars are connected respectively to the wrong terminals. This effect has to be avoided.

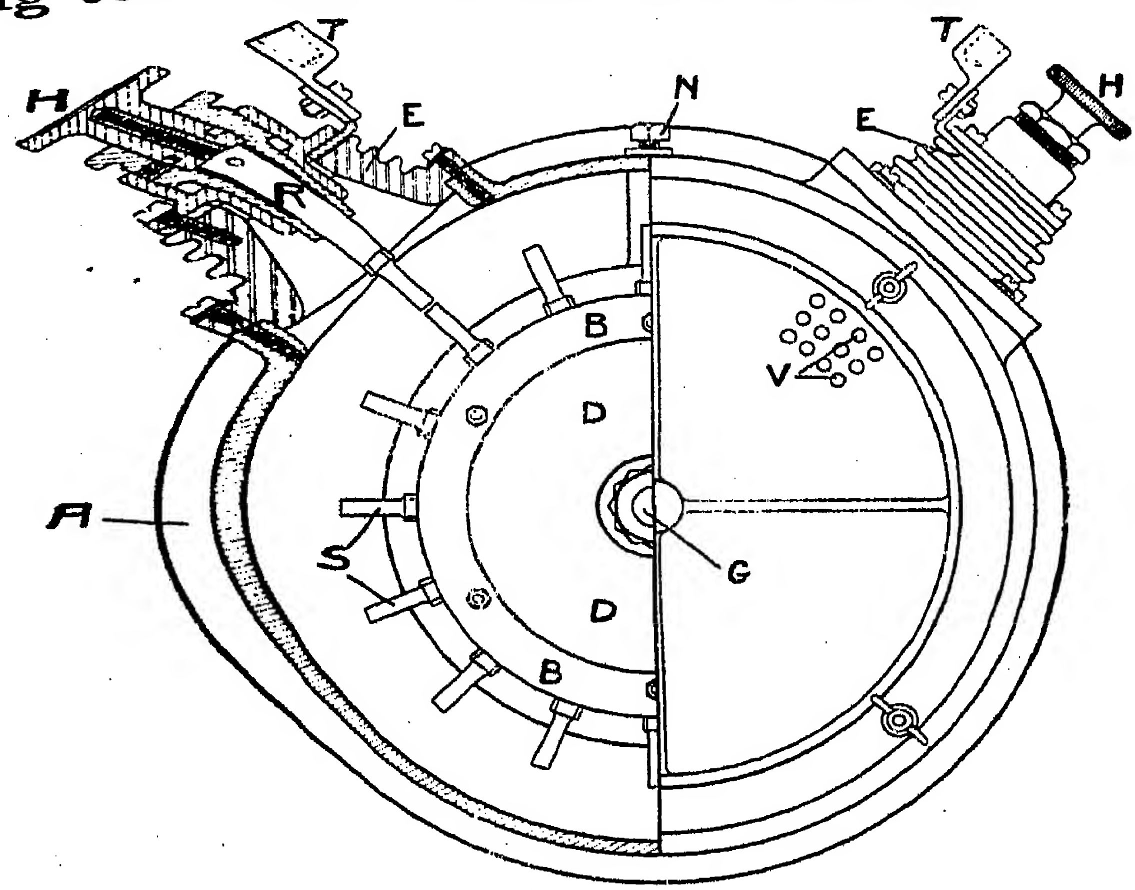

FIG. 221.—5 K.W. DISC DISCHARGER, RADIAL AND OVERHUNG TYPE.

A, Aluminium Case.—B, Brass Rim.—D, Ebonite Disc.—E, Ebonite Electrode Bushing.—G, Generator Shaft Extension.—H, Electrode Feeding-down Handle.—N, Case Nipping Screw.—R, Copper Electrode Rods.—S, Copper Studs.—T, Electrode Terminal Socket.—V, Ventilating Holes in Cover.

The Disc Discharger.—The "Battleship" type disc discharger is efficient and self-contained, but it is cumbersome, and it necessitates an extension of the motor generator bedplate. The discharger used on the special 5 k.w. set, Fig. 221, is similar in outside appearance to the 1½ k.w. disc discharger. The sparking disc of ebonite, fitted with a metal

rim and studs, is mounted on an extension of the shaft, and the disc box of aluminium overhangs the bedplate. The electrodes fitted through the box are shown at R. As the spark is synchronous with the alternator frequency, there are as many disc studs as there are poles on the alternator, namely, 16. Both the studs and electrode rods in this case are of $\frac{5}{16}$-inch copper. Behind the disc, and independently mounted on the same shaft extension in the disc box, is an aluminium fan, which maintains a cooling draught having its exit through perforations in the box cover. Heavily insulated flexible cables connect the disc electrodes with the rest of the H.F. primary circuit.

The instant of discharge, relative to the phase position of the alternator volts, is indicated by an arrow on the machine casting and a scale on the disc box, and this can be adjusted by rocking the disc box, a clamping screw finally fixing the box at the right position.

The Transmitting Jigger.—This is known as a "skeleton" jigger, as both primary and secondary windings are exposed to view. A multiple-turn primary is used with brass lug tapping connections, either one of which can be plugged through on to a copper busbar in a similar way to the "Battleship" jigger. The primary winding may have five, or six, or seven turns according to the wave-length range required, the inductance of the seven turns being about 20·25 mhys. The secondary winding consists of seven turns of heavily insulated stranded cable, with a tapping to a terminal on the front of the case at every turn. Maximum inductance, 27·7 mhys. A screw adjustment is used for varying the coupling.

The Aerial Tuning Inductance.—This is similar to the $1\frac{1}{2}$ k.w. wood boxed unit, having 20 turns, and a maximum inductance of 150 mhys.

THE RECEIVING CIRCUIT—*The Valve Receiver.*—In addition to the magnetic detector and the multiple tuner, the 5 k.w. set is usually supplied with a valve receiver—a tuner and detector combined in one instrument. The detector is a Fleming Oscillation Valve. It consists of an exhausted bulb in which is a carbon or tungsten filament such as is used in ordinary incandescent lamps. Surrounding this filament is a metal sheath having an independent connection sealed through the glass.

When the filament is glowing and the sheath is cold, it is possible to pass a small current from the filament to the sheath,

but no current can pass in the opposite direction. It is therefore called a valve. In practice, owing to the unavoidable warming up of the sheath, a negligibly small current does pass back to the filament.

The valve in operation is used as follows :—

A local battery maintains the filament at the required brightness. Connections from the two sides of the condenser in the high-frequency detector circuit, are made—one to the valve sheath, and the other through a telephone to the end of the filament connected to the negative pole of the battery. Then when the high-frequency circuit is in oscillation, the negative component of the current passes through the valve, but the positive component is completely, or almost completely, stopped. The difference of the flow in the two directions gives us the "rectified" current, and the telephone —which cannot take up vibrations of the order of the electrical oscillations—receives this intermittent current, which is further broken up by the spark groups at a frequency at which the telephone can respond and give an audible note.

Some valves are fitted with an additional screen of copper gauze covering the outside of the glass bulb, and making electrical contact with the metal cap surrounding the filament contacts. This screen protects the valve from heavy spark discharges in the neighbourhood, which appear to have the effect of fixing a charge on the glass walls of the valve which renders it temporarily insensitive. When the valve is made so that the filament is completely enclosed by the internal sheath, no external screen is necessary.

The receiver in appearance is somewhat similar to the multiple tuner, but having in addition bayonet sockets for two valves, a switch to change over from one valve to the other, and rheostat and potentiometer for the valve circuit.

It contains three tuning circuits, the aerial circuit, intermediate circuit, and the valve circuit. The "stand-bi" switch cuts out the intermediate circuit, but it still leaves an inductive coupling to the valve circuit. This differs from the circuit arrangement of the multiple tuner, which throws the magnetic detector direct into the aerial circuit on "stand-bi."

A theoretical diagram of the valve receiver when the change-over switch is on the "stand-bi" side is shown in Fig. 222.

The aerial circuit includes L_1 a variable inductance, K_1 a variable condenser, and L_2 an inducing coil. The valve

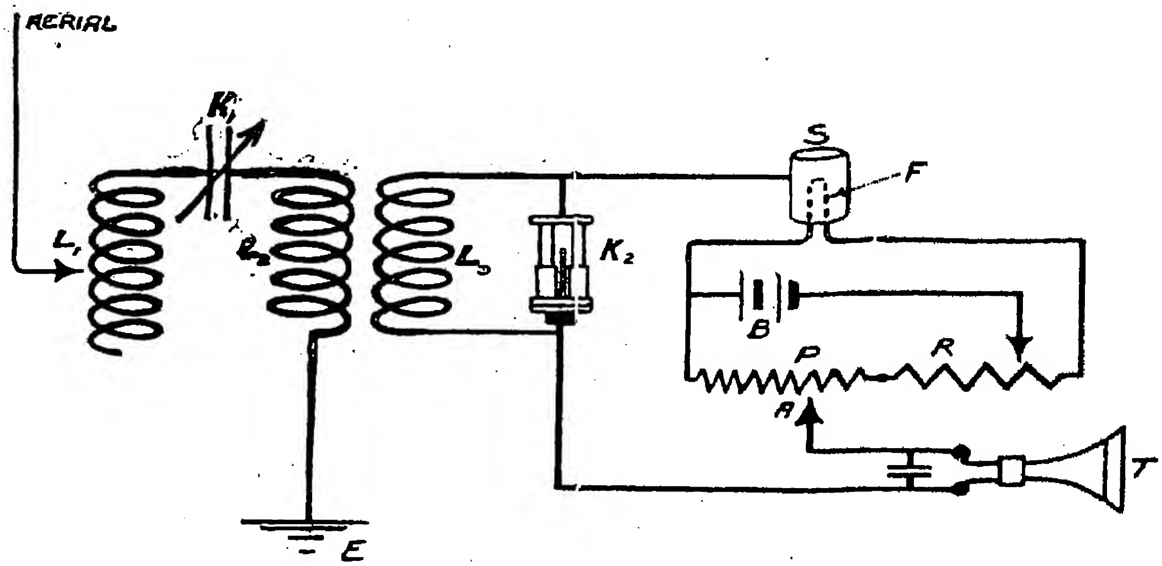

FIG. 222.—Valve Receiver (Theoretical Diagram).

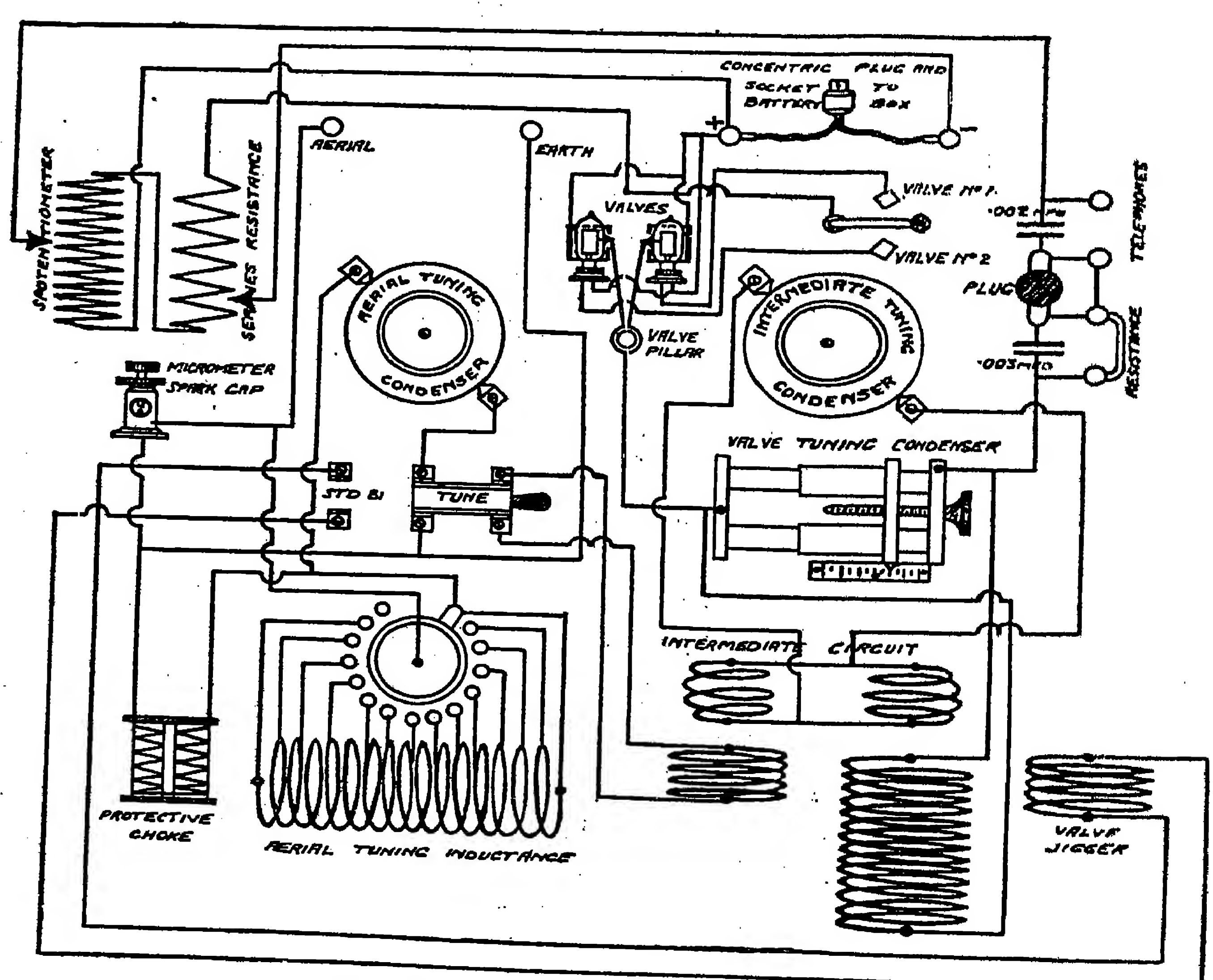

FIG. 223.—Valve Tuner Connections.

filament circuit consists of B, a 6-volt accumulator battery, F the filament, and R a variable resistance by means of which the glow of F is regulated. The valve rectifying circuit is outlined by the letters T, A, P, F, S. The telephones T are shunted by a condenser; the slider A on a potentiometer P adjusts the fixed potential between F the filament and S the sheath. Finally, L_3K_2 is the valve oscillating circuit which supplies the variable potential between F and S generated by the incoming signals.

L_3 is the jigger secondary, an inductive winding of many turns of fine wire, and K_2 a variable condenser of very small capacity, as described on p. 194.

The intermediate circuit is of the same type as the intermediate circuit of the multiple tuner, and is inserted between the aerial and valve circuits when the switch is on the tune side. The complete connections are shown in Fig. 223.

Two accumulator batteries are supplied with the receiver for giving the necessary current. Each battery consists of three cells in celluloid containers permanently connected together, and fitted in a polished teak box, having a plug socket by means of which connection may be made either to a charging switchboard or to the receiver. The batteries are of 40 ampère-hour capacity, and require a normal charging current of 2·5 ampères, the specific gravity of the acid used being 1·190.

The Charging Board.—A small charging board is supplied to be used in connection with the valve accumulator-batteries. The two bayonet lamp sockets, L, a small moving-iron voltmeter, V, with a range of from 0—10 volts, fitted with a small push button on its casing, two plug sockets, S, and terminals, for two fuses, F, are mounted on a slate slab as shown in Fig. 224. The plug sockets consist of two concentric brass rings insulated from each other, and reference to the diagram will show that the centre ring is attached to the negative lead in both cases. Four plugs are supplied by means of which the various connections may be made. Two of these plugs are attached to the opposite ends of a length of twin flexible wire, the inner contacts being connected to the ends of that part of the flexible which is covered with black braid. This ensures that when the two plugs are placed respectively in the socket on the accumulator box and the socket marked S_1 in the diagram, the negative plates of the accumulators will be properly connected to the negative charging main, because

the negative plates are connected to the inner ring of the socket on the box. A third plug is attached to one end of another piece of twin flexible wire, the free ends of the flexible being connected to the positive and negative mains on the marine switchboard, care being taken that the black lead is connected to the inner ring of the plug and to the negative main. Two fifty-candle-power carbon-filament lamps are placed in the sockets to regulate the charging current to the required amount. It is seen that if the connections are made between A and S, B and S_1, and between C and the accumulator box, the accumulators will be on charge. A depression of the push button on the voltmeter gives a reading which indicates when

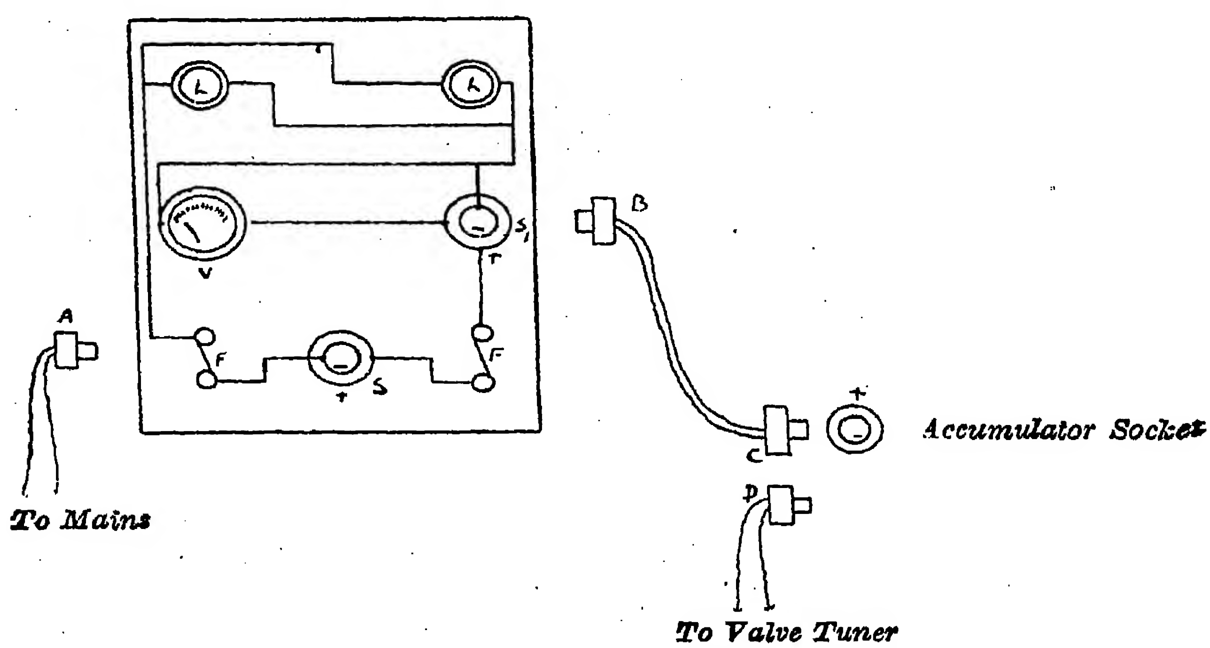

FIG. 224.—Valve Accumulator Charging-Board.

the cells are charged. The fourth plug, D, is attached to one end of another piece of twin flexible wire, carrying two lugs at its other end which are connected to two terminals on the valve-tuner. When current is required for the valve it is only necessary to remove the charging plug C and to insert the plug D. Two separate accumulator-batteries are usually provided, so that while one is being used in connection with the valve, the other may be placed on charge.

Crystal Receiver, Type 16.—A tuner combined with a crystal detector and known as a "crystal receiver" sometimes replaces the valve receiver in 5 k.w. ship and shore installations. The standard instrument for general use is technically known as "type No. 16," and is illustrated in Fig. 225. Its

range of wave-length adjustment is from 250 metres to 3500 metres. It contains two high-frequency circuits—an aerial circuit, and a detector circuit—but no intermediate circuit; and is constructed so that two crystal detectors may be used simultaneously for balanced working, or only one detector for independent working. The wiring diagram of this receiver

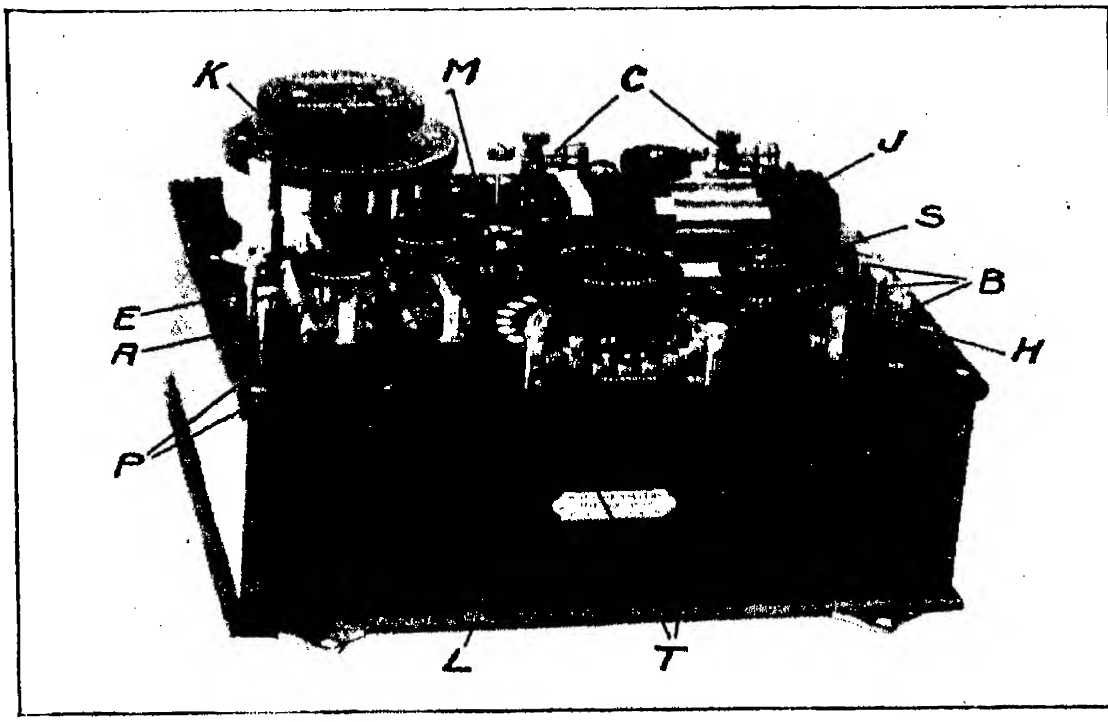

FIG. 225.—CRYSTAL RECEIVER, TYPE No. 16.

A, Aerial Terminal.—B, Battery Terminals.—C, Crystal Clips.—E, Earth Terminal.—H, Coupling Handle.—J, Jigger Condenser.—K, Aerial Tuning Condenser.—L, Aerial Tuning Inductance Handle.—M, Micrometer Spark Gap.—P, Potentiometer.—S, Range Switch.—T, Telephone Terminals.

is shown in Fig. 226. The aerial circuit—which is protected by the usual micrometer spark gap and static leakage coil to earth—includes an adjustable inductance, an adjustable series condenser, and a primary coil on a spherical former, which can be rotated on its axis to vary its coupling with the fixed secondary coil in the detector oscillation circuit.

The secondary coil is split up into three parts which are used either one, two, or three in series, to give the three ranges of the instrument. The range switch is fitted with platinum contacts, and completely disconnects the part not in use, which is a feature peculiar to this receiver. The detector oscillating circuit is tuned by a "billi" condenser,

across which is connected the crystal, in series with either a high resistance telephone, or the primary of a telephone transformer having a low resistance telephone in its secondary circuit. A separate potentiometer is connected to each crystal holder. This is a convenience for independent working, but a necessity for balanced working.

The "balanced" working referred to is a method of

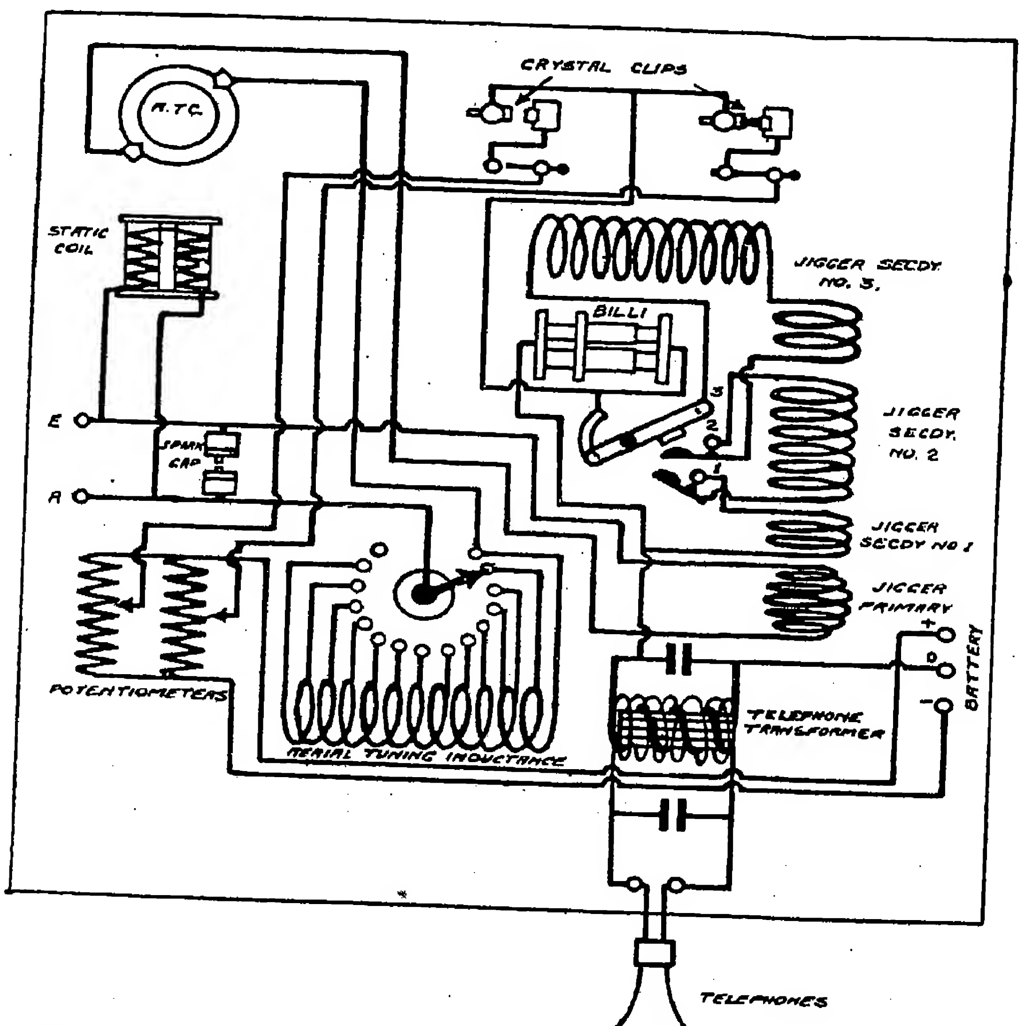

FIG. 226.—Crystal Receiver, Type No. 16, Diagram of Connections.

reception adopted to reduce interference by atmospherics. It is applied as follows :—

Balanced Crystal Working.—A crystal is placed in each holder in such a manner that when they are switched in circuit in parallel, they tend to rectify in opposite directions. This simply means that in the case of one of them the normal relative positions of crystal cup and steel plate are reversed.

Each detector is then adjusted separately in the circuit by means of its own potentiometer to give loudest signals,

the other detector being out of circuit. If now the two detectors are switched in together, the signals fall to zero, or if the crystals are a little different in quality signals can be made to fall to zero by a small movement of one of the potentiometer sliders, as no resultant rectified current then remains in the circuit. To adjust the crystals so that atmospherics are reduced to a minimum, one of the potentiometer sliders must be moved back towards the potential zero position until signals once more resume the full strength given by the crystal whose potentiometer has not been altered—suitable correction for the capacity of the extra crystal having been made in the detector oscillating circuit by readjustment of the "billi" condenser. This puts the receiver in its final working state.

It will now be found that all signals which are stronger than those which it is desired to receive, and all loud atmospherics will be considerably weakened, and if the crystals are suitably chosen, the stronger the atmospheric the weaker will be its resultant effect in the telephone. This follows because the value of the resultant rectified current for normal signals, established by the potentiometer adjustments of the two crystals, alters very little when the signal strength is much increased, owing to the fact that the rectified currents through the two crystals increase simultaneously and at much the same rate, so that the telephone current—which is the difference between the two—remains much the same as for normal signals.

If, however, the balancing crystal—the one which works with potentiometer slider put back—has a steeper characteristic than the other, which follows if it has a lower resistance, then its rectified current increases at a quicker rate than does the current for the working crystal, and therefore the difference between the two for high potential values, or strong atmospherics, grows less and signals consequently become weak.

Fig. 227 may help to explain the operation. The abscissæ show signal voltages only. Curve A is the characteristic of the balancing crystal which has little or no steady potential applied to it. Curve B is the characteristic of the working crystal which is subjected to a steady potential of 1 volt, with the result that the bend of its characteristic is shifted to the signal potential zero, so that the smallest value of alternating E.M.F. resulting from high frequency currents, works on the

best position on the characteristic for affecting the telephone current. Now, suppose the same E.M.F. is added to both crystals. Then instead of the current values being given by the corresponding ordinate of either of the curves, it is given by the difference of the two ordinates, the part between the two curves.

The current is thus seen to increase by a less amount for small E.M.F.'s than would be the case if only one crystal were in use, and for large values of E.M.F., where the curves tend to cross, the current becomes actually less than the normal.

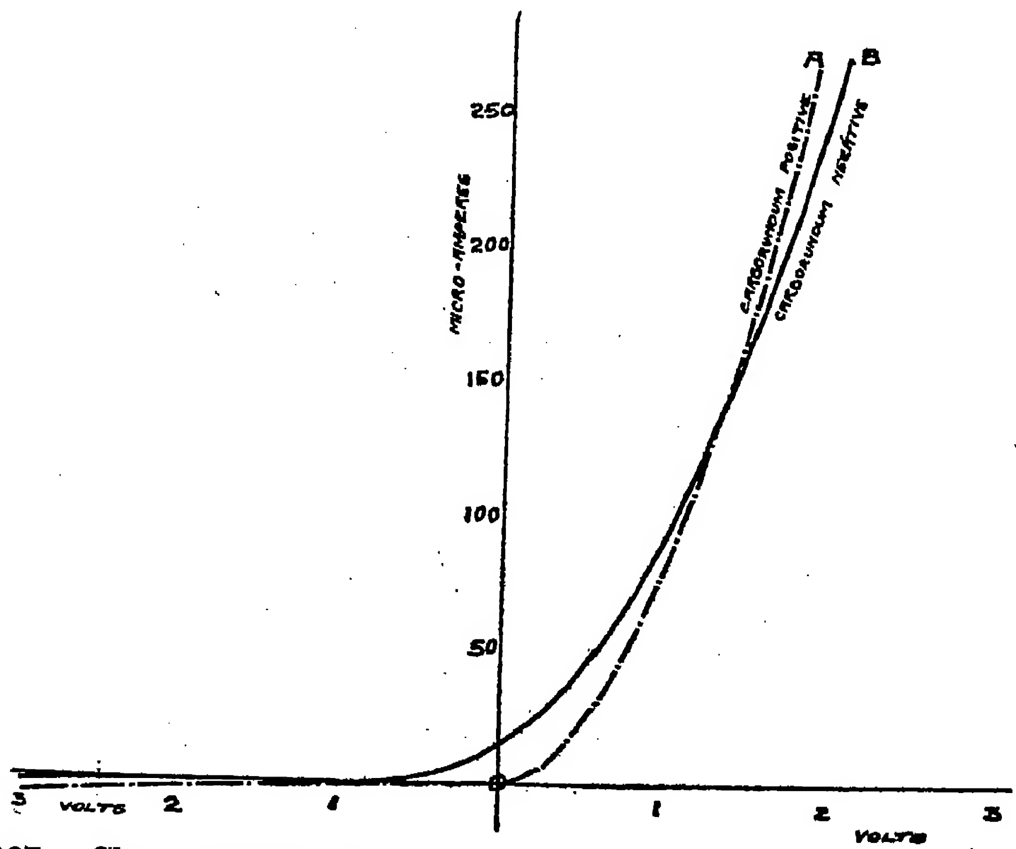

FIG. 227.—Characteristic Curves of "Balanced" or "Opposed" Crystals.

Valve detectors can be used in the same way as crystals for balanced working, and give equally good results, the above explanation holding good for them also.

Crystal Receiver, Type No. 26.—This is a supplementary receiver designed to carry up the range of wave reception on board ship to 6000 metres—its lowest wave-length adjustment being 2500 metres. The instrument can, of course, be used equally well on land, the qualification "for ship use" simply meaning that it must give the full range of tuning on an average ship aerial—which would be considered small for an

average land station—and that the complete instrument must be made up as compact and simple as possible.

The receiver is in two parts, the large aerial tuning inductance of 10,000 mhys. required to cover the range being made up as a separate unit. It is shown in Fig. 228, and Fig. 229 gives a diagram of its connections.

The open aerial circuit, is coupled to the closed detector

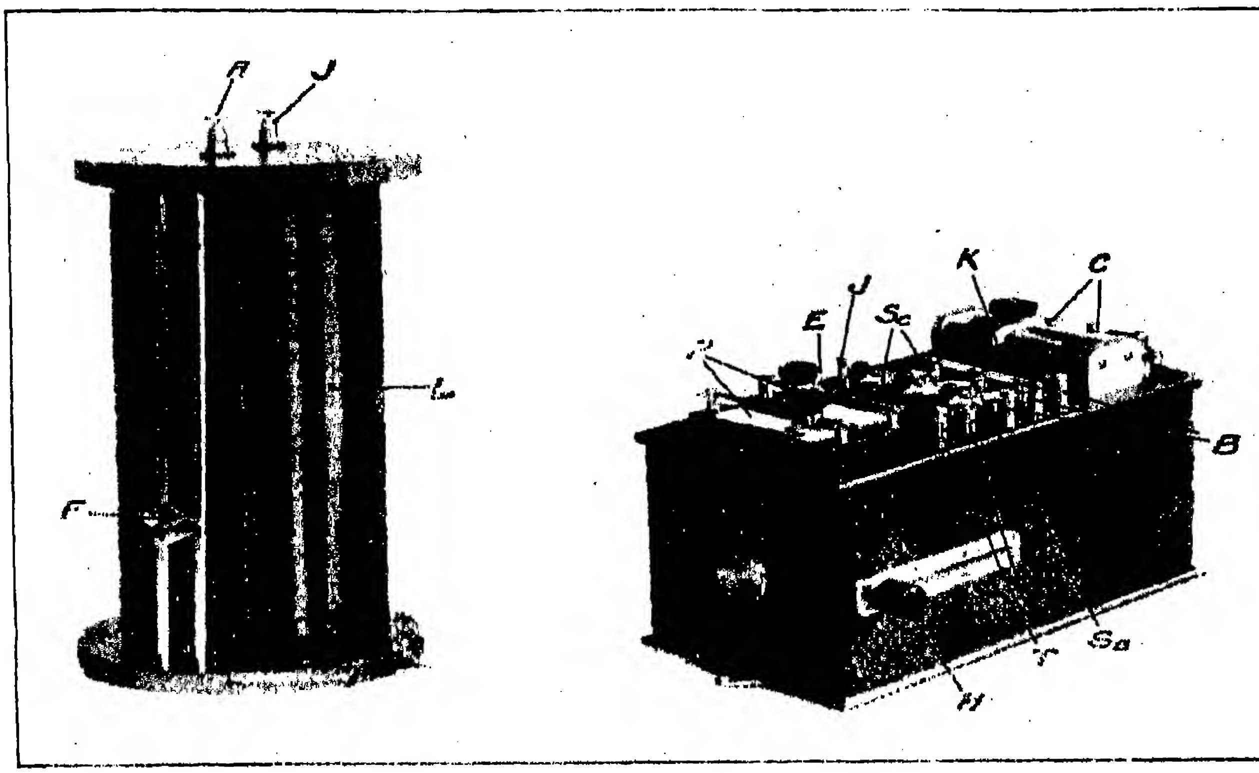

FIG. 228.—CRYSTAL RECEIVER, TYPE NO. 26.

A, Aerial Terminal.—B, Battery Terminals.—C, Crystal Clips.—E, Earth Terminal.—F, Slider Connection.—H, Slider Jigger Coupling Handle.—J, Jigger Primary Terminals.—K, Jigger Condenser.—L, Aerial Tuning Inductance.—P, Potentiometer.—SB, Battery Switch.—Sc, Crystal Switches.—T, Telephone Terminals.

circuit, by means of a coil which slides on an axis common also to the secondary coil. This movement provides a variation of coupling.

It can be understood that if the instrument is designed to give 4 per cent. or 5 per cent. coupling between the circuits at a maximum, when the full amount of aerial tuning inductance is in circuit for the top waves of the range, that when the instrument is required to work on the bottom waves of the range the coupling may reach 20 per cent. to 25 per cent., and

the minimum coupling obtainable by sliding the primary as far as possible away from the secondary may still exceed the 4 per cent. or 5 per cent. found best for working.

The primary coil is therefore split by a tapping connection, so that only part of it need be used for short-wave reception, to ensure that the coupling can be made weak enough. A weak coupling generally means that the receiver is more in

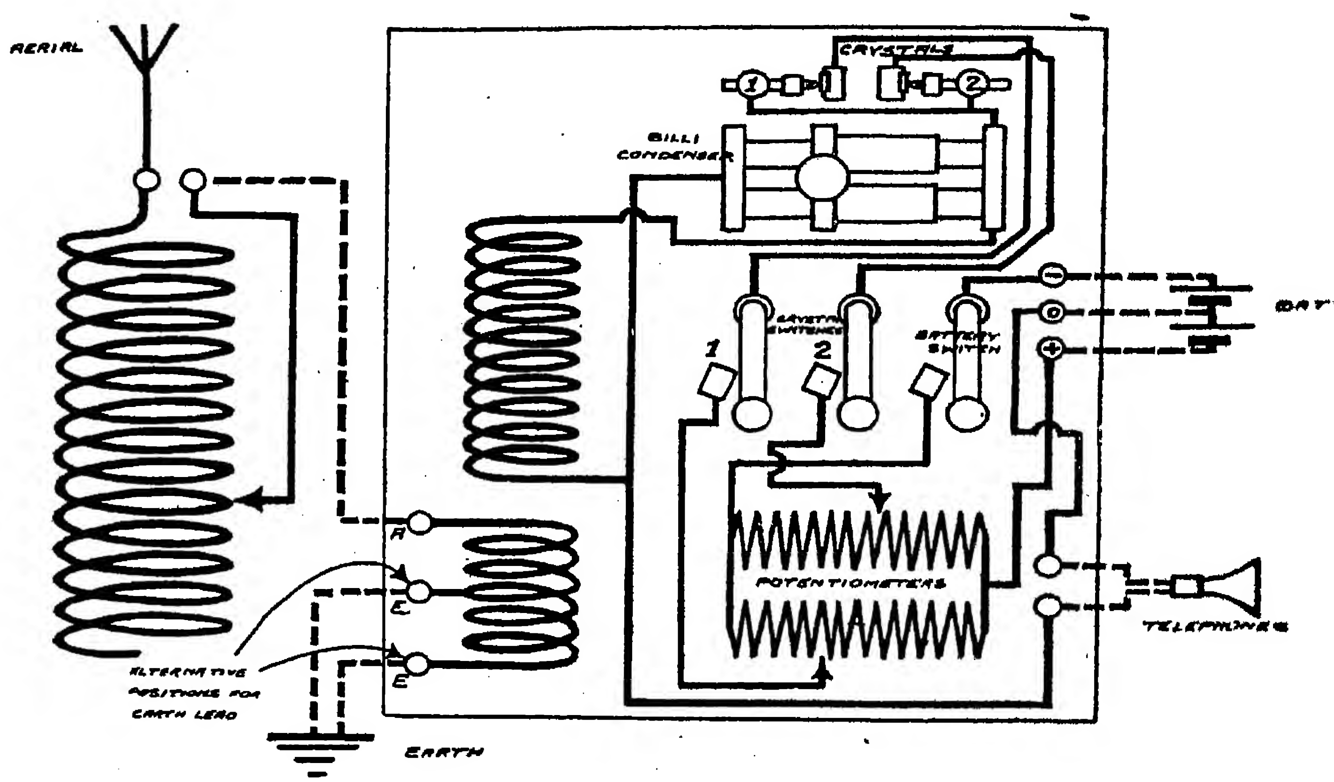

FIG. 229.—Crystal Receiver, Type No. 26, Diagram of Connections.

tune with the transmitter—strong couplings are not used in unquenched spark circuits—also that the operator has less trouble from atmospherics, and if balanced crystals are employed as can be arranged in this receiver, if desired, the elimination of atmospherics is more thorough.

The table of wave lengths supplied is true for a coupling of 5 per cent. For stronger coupling the billi condenser must be set at a lower value to adjust to the same wave length.

CHAPTER VI

PORTABLE SETS.

Portable sets—Pack set—Cabinet set—Adjustment of disc discharger.

In addition to the standard sets of apparatus already described, which are essentially designed for use on board ship, a series of portable sets is manufactured by the Marconi Company, mainly for Army use. These sets range in power from the small knapsack set of about one twenty-fifth of a kilowatt, to the motor-car set of three kilowatts. The first-mentioned set derives its power from either a small primary or secondary battery. The other sets, consisting of pack sets for transport on horse or mule back, and the higher-power installations designed for transport in field-carts, usually obtain their low frequency primary current from a small alternator directly coupled to a small petrol engine. In the motor-car outfits, the engine which propels the car is used for driving the alternator when the car is stationary.

In every case, the apparatus is designed with special consideration to weight and bulk, although when a complete installation is set up the general disposition of the circuits is the same as already described in preceding chapters. No L.F. tuning inductance is used. In all the portable types the oil condenser is replaced by tube condensers. A description of the condenser is given on p. 216. It has the particular advantage so essential to a set designed for military requirements, that a broken tube can be removed and a new one inserted quickly and easily and without appreciable alteration to wave length, as all the tubes are calibrated to as nearly as possible the same value.

Most of the sets are arranged for the transmission of three different wave lengths, and a switch is used by means of which all the necessary alterations in the various circuits may be effected in a minimum time by one simple movement. The necessity of such an arrangement will be readily understood, when it is remembered that the possibility of an enemy

reading the messages must be reduced to a minimum. By continuously altering the wave length during transmission, great difficulty in working would be experienced at a receiving station, by friend or enemy, unless means were provided for quickly making corresponding changes in the receiving circuits. A special instrument is used for this purpose known as a "Commutator" receiver. It contains three coupled circuits as in the case of the multiple tuner, but so arranged that the movement of a single switch alters the three circuits simultaneously and without further adjustment, to any one of the wave lengths transmitted by the corresponding station. A simpler form of instrument, known as a "Flexible" receiver, is installed in some portable sets. This receiver contains two circuits similar to the circuits of the simple tuner described on p. 239, and receives its name from the fact that the circuits are continuously adjustable for any wave length within the upper and lower limits.

It has been stated that the earth connection on board ship is obtained by means of a bolt screwed into the iron bulkhead. At a permanent land station, the "earth" usually consists of a number of buried plates, or a wire network buried in the earth underneath the aerial system. As the process of burying earth plates or wires takes a considerable time, a different arrangement is adopted in connection with a portable station. A copper gauze net is unrolled and laid along the ground. This serves excellently as an "earth," and can be very quickly placed in position.

The aerial is suspended from masts which are built up in sections, each section being fitted with a socket at one end and a plug at the other, all sections being interchangeable. Guy ropes are supplied with each mast.

The Pack Set.—Fig. 230 shows a pack set assembled ready for use. In the background can be seen the bicycle tube frame just as it has been lifted down from the back of the transport animal.

On one side is the $2\frac{3}{4}$ H.P. petrol motor with its oil tanks, on the other side the $\frac{1}{2}$ k.w. self-exciting alternator with disc box. A shaft which takes less than a minute to insert connects the two through the frame. In the foreground are two boxes placed one on top of the other, and in this way making all the electrical connection between them which is necessary. The lower box contains a closed iron core transformer and the H.F. primary circuit, the top box the H.F. secondary circuit,

FIG. 230.—THE "PACK" SET.

A, Alternator.—C_A, Flexible Twin Cable, Alternator to Transformer Primary.—C_K, Flexible Twin Cable Transformer Primary to Key.—C_H, Flexible High Tension Lead, Condenser to Disc Discharger.—D, Disc Box.—F, Bicycle Tube Frame.—K, Operating Key.—M, Petrol Motor.—O, Oil Tank.—R, Case containing Jigger Secondary, Aerial Ammeter, Operating Key, Crystal Receiver, Telephones, etc.—T, Case containing Transformer, Condenser, and Jigger Primary.

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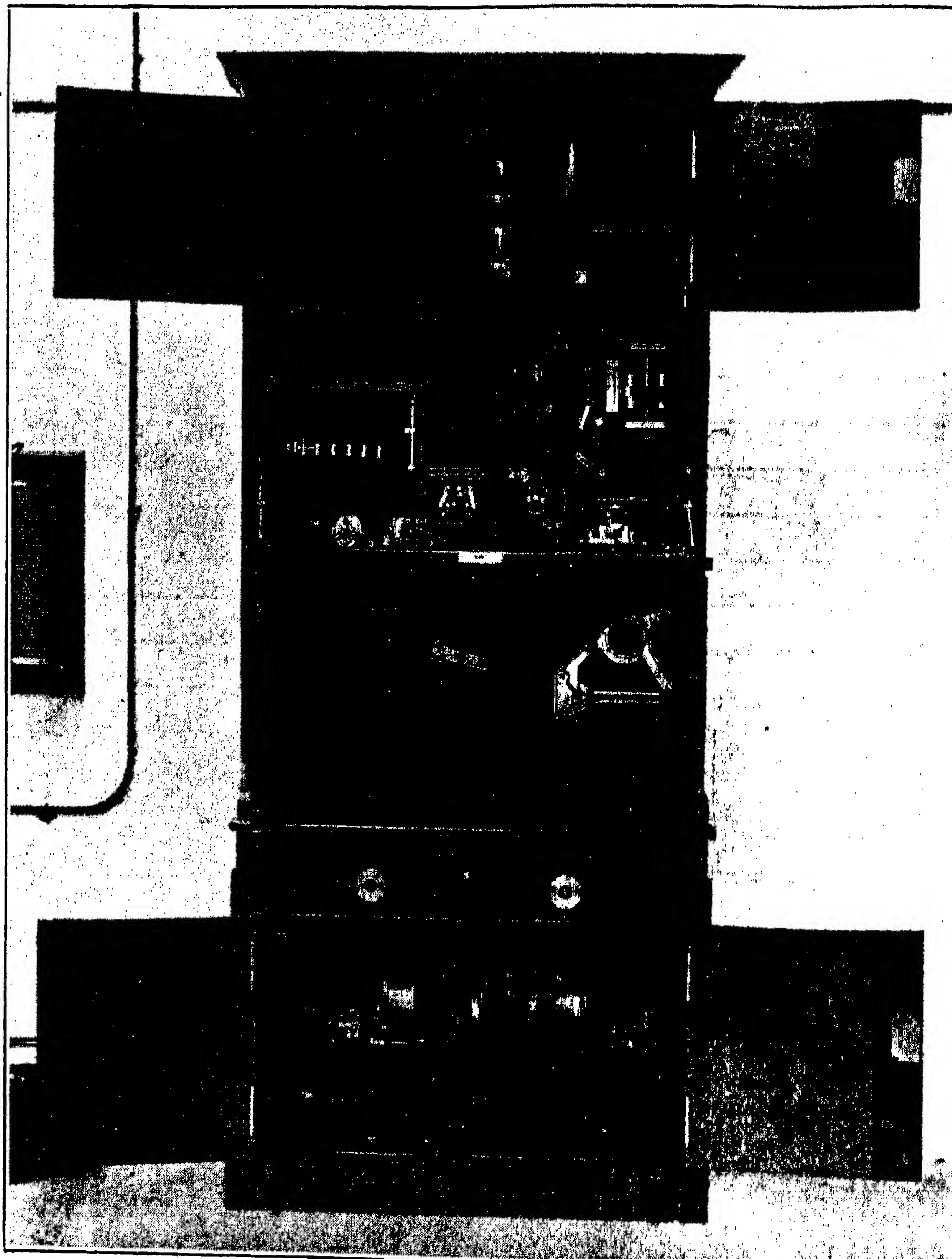

FIG. 231.—½ K.W. CABINET SET.

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the transmitting key and the receiver. The complete set, including the two masts, can be erected by men familiar with the work in six minutes.

The Cabinet Set.—This set is not intended for field service work, but being self-contained in its case, compact, and of well-finished appearance, it is very suitable for use, say on a yacht or in a private house, where a special cabin cannot be set aside for wireless purposes only. It has many of the

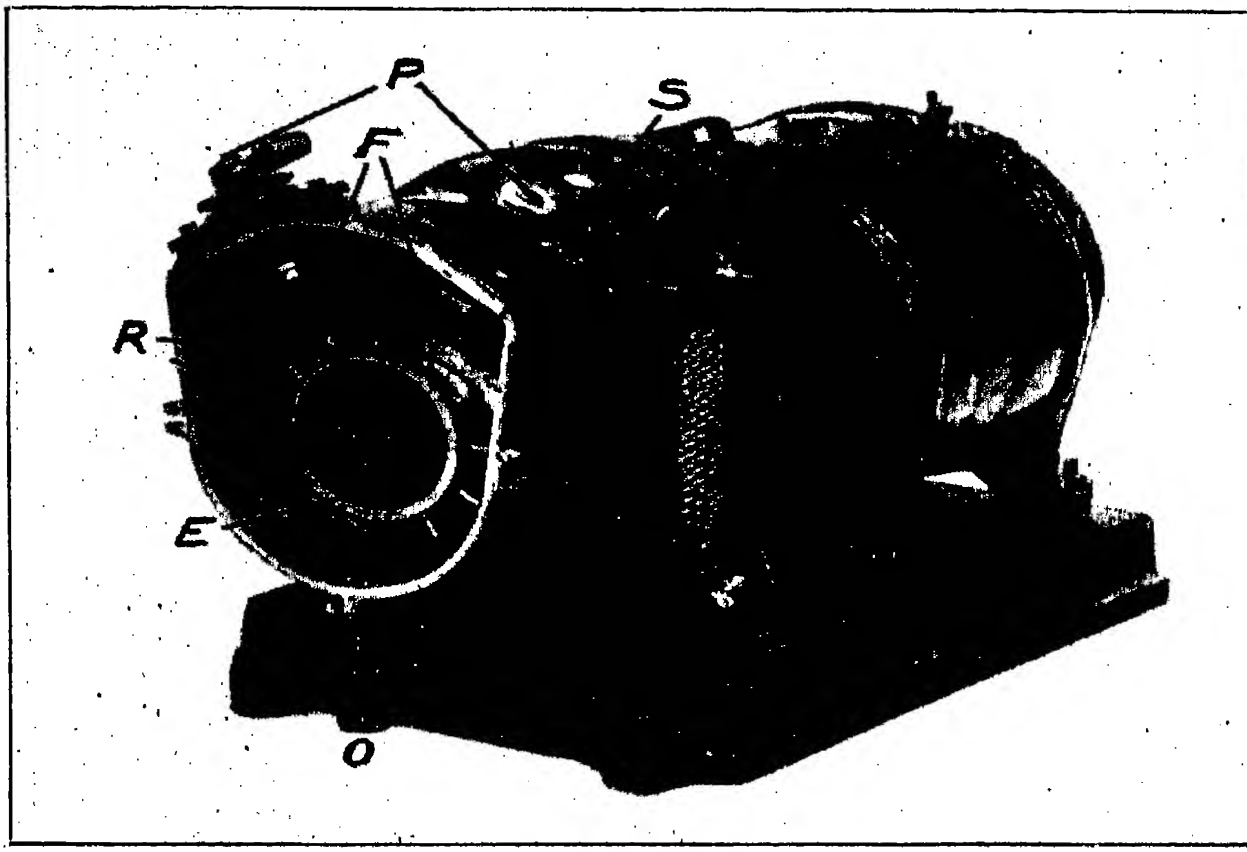


FIG. 232.—½ K.W. MOTOR GENERATOR WITH DISC DISCHARGER CABINET SET.
E, Ebonite Disc.—F, Fixed Electrodes.—P, Plug Sockets for High Frequency Leads.—R, Rotating Studs.—S, Slots with Bolts for Locking Case carrying Fixed Electrodes in Position.—O, Air Outlet Pipe from Disc Box.

features of a portable set, and is designed to communicate with portable sets. The whole of the apparatus is contained in a small oak cabinet 70 inches high, 30 inches wide, and 16½ inches from back to front when closed (see Fig. 231).

The bottom section of the cabinet contains a small motor-generator (Fig. 232) capable of giving an output of ½ k.w. A rotary disc discharger is mounted on one end of the shaft, and overhangs the bedplate. Behind the disc is a fan which expels the heated air from the disc box when the machine is running.

Guard lamps for protecting the windings of the machine are on the wall at the back of this compartment.

The closed oscillatory transmitting circuit is contained in the section of the cabinet immediately above the motor-generator.

It consists of a closed iron-core air-cooled transformer, a glass-tube condenser battery, a variable high frequency inductance, the primary of a jigger, and a two-way switch for changing the wave length of the closed oscillatory circuit.

The secondary of the jigger is mounted in the third section of the cabinet, immediately above the jigger primary, and may be adjusted by means of simple clamp connections to suit any aerial within reasonable limits. The receiver is in a neighbouring compartment to the jigger secondary. It is of the "flexible" type already referred to, adapted for use with a carborundum detector, but other forms of detector can be used if desired. Its range is from 300 metres to 1000 metres. In a small partition between the receiver and the transmitter secondary is a tuning buzzer, by means of which the receiving apparatus may be adjusted for the reception of any particular wave length.

The top section of the cabinet contains the aerial tuning inductance, a small compartment for accommodating the battery used in connection with the receiver potentiometer, and a small compartment for the storing of any spare material. On opening the section of the cabinet containing the receiving apparatus, it will be found that the cover provides a useful desk, on which is fitted the transmitting key. The back contact of the key automatically disconnects the receiving circuit when transmitting.

Immediately above the motor-generator section are three key sockets for controlling the starter, and motor and alternator field regulators. A detachable box key handle is provided, which fits in either of the three, and thus on to the squared end of the corresponding regulator spindle. Guard lamp boards are also fitted in the section occupied by the machine.

Two heavily bushed terminals pass through the top of the cabinet, to which the aerial and earth connections are made.

Adjustment of Disc Discharger.—The correct adjustment of the discharger is one of the most important points to be attended to in the whole of the transmitter, and the smooth working of the station depends largely on this.

An incorrect adjustment of the disc, amongst other things, will cause excessive strain on the transmitting condenser, excessive strain on all the insulation of the primary transmitting circuit, arcing at the manipulating key contacts, and a bad toned note.

The main condenser, especially when designed for use with a disc discharger, is supplied with safety spark points, which protect it from breakdown due to excessive voltage. The spark points should be set at a distance of about 8 millimetres.

The fixed electrodes of the discharger should be adjusted so that they nearly touch the ends of the disc studs, care being taken to turn the armature completely round by hand in order to make sure that the studs are of equal length and all clearing the fixed electrodes.

The machine may then be started and the manipulating key depressed, when a spark should take place between the fixed and moving studs. If this spark be of a ragged character, or if sparking takes place very freely at the safety spark-gap, the phase relationship between the fixed and moving electrodes should be slightly altered. This alteration is made in one of two different ways. In one type of machine the casing in which the stationary electrodes are fixed may be moved, whilst in another type (already described) the disc coupling may be adjusted. In either case, if the sparking be bad, the relative positions of the fixed and moving studs must be varied until a position is found in which sparking at the safety gap and key contacts is reduced to a minimum. In this position the spark will be found to possess a good tone, which may be slightly raised or lowered by speeding up or slowing down the machine.

On looking at the rotating disc while sparking, due to an optical effect, it appears to be standing still. When the position of the fixed electrodes is correct the disc apparently remains extremely steady, but if the position is not correct it appears to jump about in an erratic manner. When the correct phase position has been found, a maximum aerial current will be obtained (provided, of course, that the various circuits have been properly tuned), which will be indicated by the intensity of glow of the tuning lamp. This lamp therefore provides a good means of determining when the correct adjustment has been obtained.

CHAPTER VII.

Faults.

Faults—Testing—Various circuits—Various instruments—The buzzer circuit—Sparking buzzer—Shunted buzzer—Improvised shunt for converting sparking buzzer to shunted type—Excitation by means of shunted buzzer—Different methods of exciting for tuning purposes—Improvised receiving circuit.

The general design of the standard apparatus used in any of the low-power sets made by the Marconi Company, is of such a nature as to render it almost "fool-proof." The dimensions of all parts are such that they can carry loads much heavier than those used in actual practice without fear of injury; and the insulation is of a most substantial character. Nevertheless, the nature of the service demanded from the apparatus is the occasional cause of a breakdown. The vibration of a ship in a heavy seaway may result at any time in minor breakages, such as the snapping of a wire or the working loose of a connection, but as a rule in a properly installed equipment very few occasions arise on which a fault may not easily be rectified. During an examination for the Postmaster-General's certificate of efficiency, however, the candidate is often faced with an installation in which a great number of superficial faults have been made in order to test his knowledge. Each circuit will therefore be once more discussed in the same order as before, bearing this fact in mind.

The Direct Current Circuit.—The converter must first be started. The main switch is therefore closed after making sure that the starter is "open," and the starting handle brought over on to the first stop. Perhaps the armature will not commence to rotate. Should the guard lamp across the armature glow, it indicates that the feeding and distributing mains are properly connected to the main switch, and that the fuses of the latter are intact. The brushes may then be examined to see if they are making proper contact with the commutator. After the brushes have been properly adjusted,

a second attempt may be made to start the machine. If the armature still fails to rotate, a heavy arcing spark may be found to take place between the contact of the starting handle and the studs on allowing the former to come back to a neutral position. This indicates a disconnection in the field circuit, and is due to the inductive effect set up by the sudden breaking of a circuit containing inductance (the armature coils).

The field circuit may be found to be interrupted at any of the following points :—

One or both ends of the no-volt release winding may have been disconnected from the terminals on the face of the starter. A break may have been made in the series resistance of the field regulator or the starter, or one of the leads between the various parts of the circuit may have been disconnected. The connection from one end of the field winding to the brush, which is common to both field and armature circuits, may have been disconnected. Any external disconnection may, of course, be easily found and remedied. A break in the resistances may be found by first disconnecting the starter and field regulator from all leads, and by placing a galvanometer and dry cell in series between each pair of adjacent studs. A deflection of the galvo needle indicates that the connections are all right.

After successfully starting the armature, it may be found that the starting handle will not be held up against the no-load release. This may be due to the following causes :—

The no-volt release winding may have been shorted with a small piece of wire. The armature of the over-load release may have been jammed hard up against the stop, thus shorting the no-volt release ; or too much tension may have been put on the antagonistic spring contained in the barrel of the starting handle.

Primary Circuit.—After the converter has been started, a glance at the pilot lamp on the A.C. switchboard will show whether alternating current is being delivered to the board. If the lamp does not glow, the alternating current brushes on the slip-rings, the leads from the brushes to the lamp, and the lamp itself should be examined and any disconnection made good.

If the switch on the A.C. board be now closed, and the manipulating key depressed, the armature of the magnetic key should vibrate. In the case of the failure of the magnetic

key to work, the key contacts and side lever contacts should be examined to see whether paper insulation has been inserted, and the connections between the switchboard, transformer primaries, iron-core inductance, and keys should be examined. If the operator is sure that all the external connections of the circuit are right, and if he is unable to obtain a deflection of either the voltmeter or ammeter, he may give attention to the connections behind the switchboard. A galvanometer may be used to test all the internal connections of any part of this circuit in the manner already described.

H.T. and Closed Oscillatory Circuits.—As there is no simple indication of the H.T. circuit being "O.K." in itself, it may be examined for faults together with the closed oscillatory circuit. The size of the plain discharger spark-gap in the latter, should be first adjusted to the required width for the particular wave length required—namely, three or four millimetres for the 600 metre wave, and six or eight millimetres for the 300 metre wave. If the discharger is of the rotary disc type, the minimum gap has to be made as small as possible, consistent with any inequalities in the lengths of the disc studs. The transformer secondaries, and the main condenser banks, should then be placed in series or parallel as required, and the connections throughout the circuit should be examined. Care should be taken that the ebonite insulating strips between the copper strip connections of the closed oscillatory circuit are in their correct positions, otherwise sparking will take place between them instead of at the spark-gap. After all external connections have been verified a spark should be obtained. Failing this the choke coils may be tested for continuity with a galvo and Q cell. As the resistance of the transformer secondaries is several thousand ohms, the dry cell and galvo are useless for testing them for continuity. The secondaries should be tested, therefore, by means of a cell and a pair of telephones joined in series across the terminals, as in Fig. 233. A hissing sound in the 'phones on making a rubbing contact between A and B denotes continuity. Absence of such hissing indicates some internal disconnection, which must be put right.

The main condenser may then be tested for a breakdown. The two banks should be tested separately, a good method being to connect the induction coil of the emergency gear across the terminals. If a small spark (three or four millimetres at the outside) be obtained at the discharge rods on

depressing the key, the condenser is in a good condition. If a spark cannot be obtained, or if it fails at about one millimetre,—the oil in the condenser puncture would probably support a millimetre spark,—the faulty banks should be lifted out of the container by means of the cradles and allowed to drain. The induction-coil test may then be again applied, when a spark will be seen to take place inside the condenser through any broken glass plate which may exist. A broken or cracked glass plate may also be detected by placing a light at one end of the bank and looking through from the other end. When the position of a broken plate has been determined, it is sometimes possible to insert a new one by gently forcing it forward from one end through the bank, so that it pushes out before it the broken pieces of the old plate at the other end of the bank. This method is to be recommended if it can be done effectively, as it avoids the long operation of taking the condenser to pieces and rebuilding.

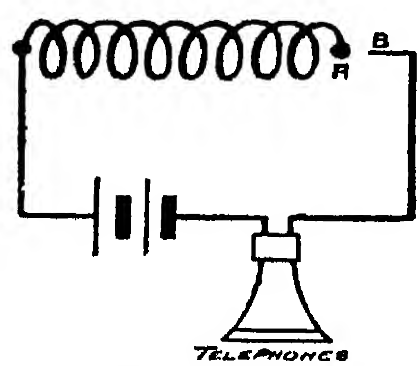


FIG. 233.—Test for Induction Coil Secondary.

But plates do not always break down singly. When one goes, the local sparking will sometimes cause the breakdown of neighbouring plates by overheating due to the burning of the neighbouring zincs. The replacement of more than one plate can sometimes be managed without dismantling, by slackening the nuts on the ends of the lug bolts and spacing out the plates and then pushing through the new plates.

If, however, the zincs are badly burnt, or some have torn lugs, they must be removed; and again, if broken glass has found its way to the bottom of the cradle and cannot otherwise be cleared away, then the condenser will have to be partially dismantled before the repair can be effected.

When rebuilding, be careful to see that consecutive zinc sheets have their lugs arranged so that they fit alternately first on one pair, then on the other pair of lug bolts, as described on p. 155. If this is not done, the spark will again fail. But this time the fault will be an internal short circuit in the condenser due to the zincs not being all connected up in the right way. When the condensers and transformer are found to be electrically satisfactory no difficulty should be encountered in obtaining a spark.

The Radiating Circuit.—As this is a simple series circuit, an examination of the connections is all that is necessary. The earth arrester may be examined to see that the two plates are not shorted by corrosion or any foreign matter, although a "short" would affect reception and not transmission. Tests for continuity in the jigger secondary winding and aerial tuning inductance may be made by means of a dry cell and galvanometer, and, of course, the insulation of the aerial must be examined, as a direct earth would result in failure to set up oscillations.

The Receiving Circuit.—Before attempting to receive signals it is necessary to wind up the clockwork of the magnetic detector. This clockwork is of a robust character and very seldom gets out of order. If the mainspring breaks, which is a very unusual occurrence, a spare is provided in the repair box. The operator, however, as most generally happens, may be unable to effect a clockwork repair, then, if no other receiver is handy, it becomes necessary for him to turn the pulley by hand ; or a fan motor may be adapted with a certain amount of ingenuity to drive the pulley.

The primary and secondary windings of the detector may be tested for continuity by means of a cell and galvo, and if a break is found, the tuner connections may be transferred to the extra set of coils with which the instrument is provided. Then at the first opportunity the broken coil may be replaced by one of the spare ones invariably supplied to a station. In fitting a new primary it will be found necessary first to slip the iron wire band off the pulleys, untwist it where it is joined, and undo it, then cut away the thread binding one end of the primary winding to the glass tube on which it is wound, so that it may pass through the secondary bobbin, and then off the iron wire band. When the primary has been placed in position the loose end must be rebound with one or two turns of thread. If it be found necessary to fit a new moving band, the two ends should be joined by means of No. 36 iron wire, a reel of which is supplied. The tension of the band should be adjusted so that it is held taut and moves at a constant speed. If no signals are heard in the telephones, the following points should be attended to. First examine the 'phones. The diaphragms can be lightly tapped with the finger-tip to see that they are free from the magnets, and not kinked, but a pencil point must not be used for this purpose.

See that the diaphragms are properly fixed and that no paper has been placed between them and the magnets, thus jamming them and preventing proper working. See that no "short" is caused by the ends of the flexible leads being in contact with the metal parts of the head gear. A good method of testing the 'phone leads and magnet windings for continuity is as follows: Place one of the pin-plugs on the ends of the leads between the teeth, and rub the other plug with a piece of metal —a tommy or key will serve. A hissing sound in the 'phones corresponding to the rubbing of the plug indicates that the 'phones are in good order. The electro-magnets are affected by the small currents due to galvanic action set up in the body. Next see that the telephones are not shorted in any part of the circuit outside their own leads. A small piece of wire may have been connected across the short-circuiting contacts of the manipulating key, or the contacts themselves may be touching. Another piece may have been put across the condenser terminals, and still a third piece may have been connected across the detector terminals.

The micrometer spark-gap should then be examined to see that it is not screwed tight home. If the spark points are touching, a direct path to earth is afforded for the received currents. The earth arrester must also be examined for a short, as this would also afford a direct path to earth for the received currents.

Follow out the connections from the two plates of the earth-arrester to the aerial and earth terminals of the multiple tuner, and see that the latter is properly connected to the primary of the detector. See that the 'phones, condenser, and short-circuiting contacts are properly connected to the secondary of the detector.

The various circuits of the tuner may be tested for continuity by means of a dry cell and galvanometer. It should, however, be remembered, that the high frequency currents generated by the received signals are sometimes so weak that dust on switch contacts is enough to destroy them, whereas the normal current from a dry cell through a detector galvanometer under the same conditions is strong enough to force its way through. Only a very weak current, therefore, should be used for testing purposes, and if a reflecting galvanometer is available, sensitive to 1 microampere, this should be used in preference to the ordinary detector galvanometer. Failing this, a rough but fairly sensitive test is the method already described for testing the

continuity of telephone leads and magnet coils, the telephones in the present case being placed in series with the circuit under test.

For cleaning contacts, a piece of pasteboard—such as a visiting-card—is very useful. It can be slipped under the brush of a switch arm and then moved backwards and forwards, cleaning and burnishing the surfaces, but care must be taken in removing it, so that no glaze or paper fibre remains between the contacts. If a breakdown be discovered which cannot easily or conveniently be repaired, it may be found expedient to construct a temporary "stand bi" circuit for aerial and detector, in order to carry on reception. What is required is a series inductance coil and a series condenser. The first of these may consist of about 100 spaced turns bare No. 20 copper wire—a large reel of which is supplied in the repair box—wound on a dry wood former about 3 inches diameter,

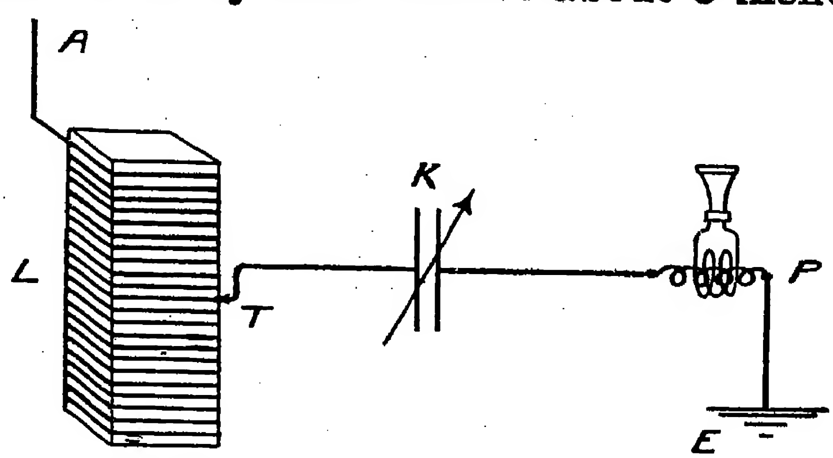


FIG. 234.—Improvised Receiving Circuit.

made up by the ship's carpenter or by the operator himself. Adjacent turns, of course, must not touch. For the condenser, either one of the three adjustable condensers on the tuner known to be sound will do. Then the circuit will be connected as shown in Fig. 234. The aerial, A, is connected to one end of the improvised inductance, L. Connection may be made between one side of one of the tuner condensers, K, and the inductance, by means of a short length of 2½ ampère flex, to the other end of which a tie clip, T, has been soldered. The other side of the condenser is connected to earth through the primary, P, of the magnetic detector. To vary the inductance for tuning it is only necessary to alter the position of the clip, T.

The Emergency Gear.—The accumulator faults have already been discussed.

On depressing the manipulating key, the hammer of the induction coil should begin to vibrate. Failing this, the connections between the switchboard, coil, and key, should be examined. The coil and key contacts should be examined to see that they are screwed up tight, and that no paper has been inserted, and the coil contacts should be properly adjusted. The ends of the primary winding should be in good metallic connection with the terminals on the supporting pillars.

The connections behind the emergency switchboard, and in the base of the coil and key, may be tested with the cell and galvo.

The discharge-rods must be connected to the secondary terminals of the coil, by means of the small choke coils.

As has already been explained, the simple emergency set is worked with a plain aerial spark. In very wet or foggy weather it is found rather difficult to obtain a good spark on account of the insulation of the aerial breaking down. A small condenser inserted in the aerial helps to overcome this difficulty, although the spark produced does not give nearly such powerful results as the proper plain spark. Two of the main condenser spare zincs may be fixed on the opposite sides of a spare glass plate and held in position by means of rubber tape. One zinc should be connected to the end of the aerial at the Bradfield insulator, and the other zinc to one of the coil discharge rods, the other rod being, as usual, connected to earth. The spark obtained will be found to be much longer than the ordinary plain spark but not nearly so fat, and it will not work so far. This device is only to be used in extreme cases. Alternatively, the coil secondary may be connected to the main condenser of the 1½ k.w. closed oscillatory circuit, as already described on p. 199, in which case, although only a very short spark is obtainable, the arrangement is capable of effective transmission to a considerable distance.

The fuses on the marine switchboard may blow, and, of course, where this has occurred the fault is plainly seen. The fuse in the centre, along the bottom of the board, is for the protection of the coil when working from the accumulators; and the other two are in the main charging and working circuit. These fuses will blow at about 15 ampères.

SPECIAL NOTE.—*In order that tests may be carried out rapidly and efficiently, it is absolutely necessary that the wiring diagrams of the various pieces of apparatus and the various circuits should be committed to memory.*

As the galvanometer plays a very important part in the testing of the apparatus, care should be taken to see that it is in good condition itself. Operators under test have been known to discover faults in a circuit which never existed, merely because they failed to see that the galvo needle had been jammed into a fixed position.

The Buzzer Circuit.—The receiving circuit may be tested by means of the buzzer. This piece of apparatus is similar to an ordinary electric bell from which the gong and hammer have been removed, but generally its scheme of wiring is different. A typical diagram of connections is given in Fig. 235. F is an iron frame on which two electro-magnets, M, are mounted. An armature, D, fixed to a spring, G, is attached to the frame and carries a contact, C, which is ordinarily at rest against an adjustable contact, C_1. The iron frame is connected to the terminal marked E, the adjustable contact to terminals marked A and K, and the magnet winding to the frame and terminal B.

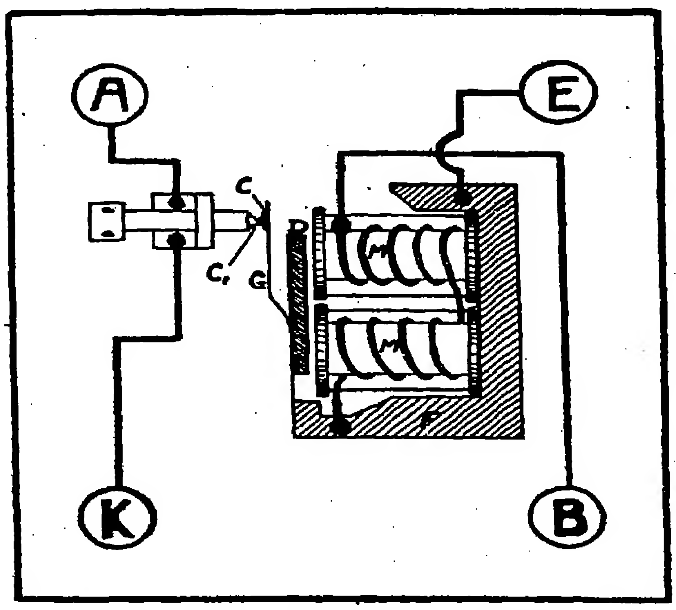


FIG. 235.—Sparking Buzzer.

If one or two cells be joined through a small key, between the terminals B and K (battery and key), a depression of the key allows a current to pass through the coils. The armature, D, is attracted, and the circuit is broken at C, the armature being immediately released. By this means an intermittent current is made to traverse the circuit, and a small spark is formed between the contact points. One of the contacts may be connected to a short aerial wire (two or three feet), by means of the terminal A, and the other may be connected to earth through the terminal E; the arrangement thus produced being a feeble plain-aerial transmitter, capable of setting up oscillations in the receiving circuit if the latter be properly connected up. If the buzzer is wired as shown in Fig. 235, the waves sent off will have a length determined by the length of the short buzzer aerial, but if ordinary electric bell wiring is used the capacity of the buzzer

itself adds to the resultant wave length. This would not matter if the only effect required was to excite a receiver circuit as a test for continuity, but as a method of measuring the natural period of the transmitting aerial, it would be faulty.

The difference between the two methods of wiring, is, that the call bell generally has the magnet windings connected between the terminal marked B in Fig. 235, and the fixed contact C_1, and if C_1 is connected to the aerial, and the armature contact—and therefore the magnet poles and yoke—is connected to earth, there exists a capacity between the windings and the magnet poles which affects the transmitted wave; whereas

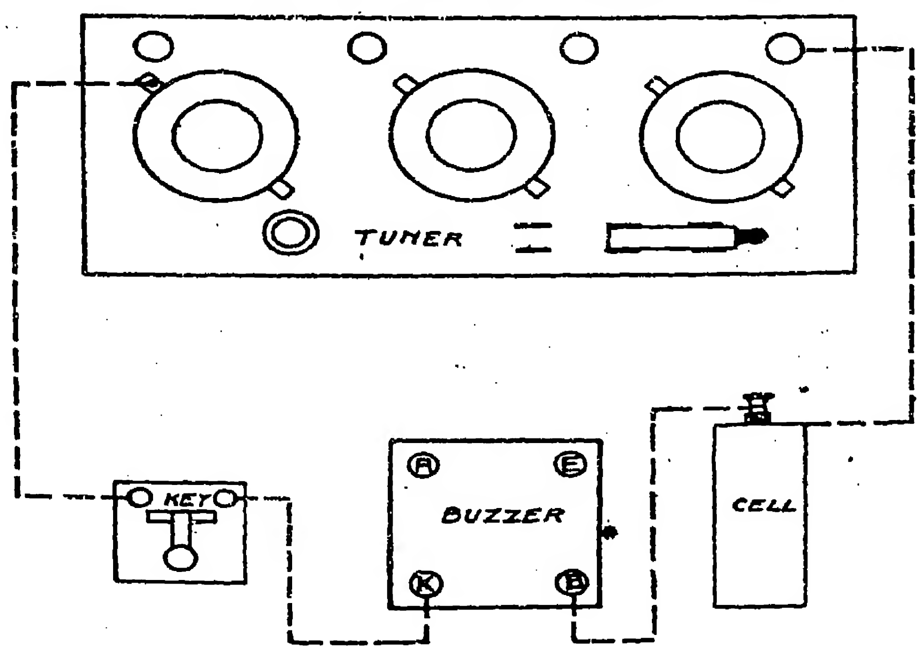


FIG. 236.—Shunted Buzzer Circuit Connections (External).

in Fig. 235 the windings and the yoke are both on the earth side of the sparking contacts, so that no buzzer capacity is introduced to affect the transmitted wave.

An alternative arrangement of the buzzer circuit, and one which is more useful, is shown in Fig. 236. A slight modification of the buzzer itself is first necessary, this modification being the inclusion of a non-inductive resistance coil, S, between the terminal, B, and the frame, Fig. 237.

This resistance is, therefore, shunted across the buzzer electro-magnet windings, and a buzzer of this type is called a "shunted" or "tuned" buzzer, while the ordinary un-shunted buzzer is called a "sparking" buzzer.

The shunted buzzer, key, and cells are connected up in series, one end of the series being connected to the earth

terminal of the multiple tuner, and the other end being connected to one side of the tuner aerial tuning condenser, as shown in Fig. 236. If the other terminal of this condenser be used, it is impossible to pass a current through the circuit, as the condenser is not a conductor for D.C. current. The complete internal connections are shown in Fig. 237.

Excitation by Means of Shunted Buzzer.—Up to the present, a condenser has been used for storing up energy to excite an oscillatory circuit. Energy may, however, be stored up or applied to the inductance of such a circuit.

When a current is sent through an inductance coil, a

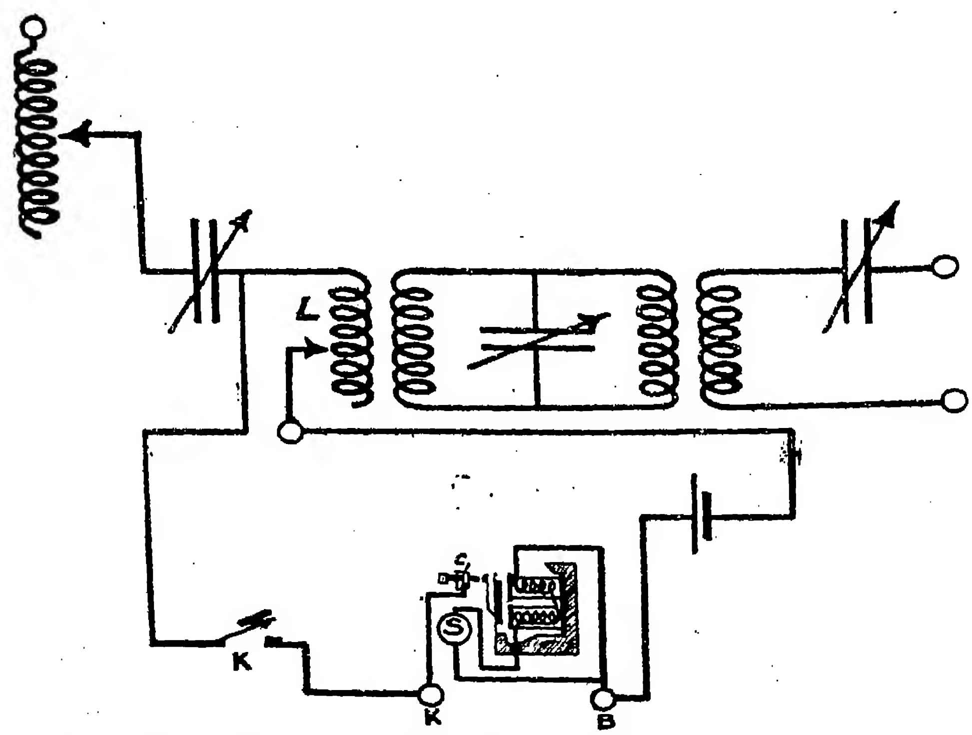


FIG. 237.—Shunted Buzzer Circuit Connections (Internal).

magnetic field is set up round it which remains constant as long as the current remains constant. If the current be suddenly interrupted, the energy of the magnetic field is transferred to the circuit, and if the inductance forms part of an oscillatory circuit, oscillations are set up.

In Fig. 237 the circuit containing the inductance, L, the key, K, and the buzzer has an intermittent current flowing in it. The inductance of the buzzer electro-magnet windings ordinarily causes a spark to take place between the contacts, and thus the interruption of the current takes place more or less slowly. In the shunted buzzer, the energy stored in the inductance of the magnet windings finds a path through the

non-inductive resistance S, and thus the sparking is eliminated, the current through L is interrupted extremely suddenly, and the energy stored in L sets up oscillations in the aerial circuit.

If, now, the intermediate condenser be set to a value for any particular wave length, the aerial and detector circuits may be adjusted until they are in tune. By altering the intermediate condenser values, and by tuning the other two circuits to the altered adjustments, the tuner may be calibrated throughout for any particular aerial with which it is being used, and thus the different circuits may be placed in syntony for the reception of any particular wave when on the tuned side.

Special Notes relating to Buzzer Tests.—When the buzzer is connected up in the second manner, the production of signals in the telephones, when on the "stand bi" side, is not an indication that everything is correct. It will be found that signals are produced even when the iron band is not rotating. The reason of this is, that the inductance-charging current is passing directly through the primary of the detector and inducing currents in the secondary, the two windings acting as a step-up transformer. This is, however, a good test for continuity of the windings.

When on the tuned side it will be found impossible to obtain a vibration of the buzzer armature, if the tuning switch remains on the first stop. This is because the small block condenser inserted in series for the reception of very short waves is in series with the buzzer circuit, thus preventing the passage of the current. In order, therefore, to test or tune the three circuits, the tuning switch must be placed on the second, third, or fourth stop.

Use of Buzzer for Exciting Transmitting Circuits.—The transmitting circuits may be very easily tuned by means of the buzzer. The following figures show the connections for making various tests in which the multiple tuner is used as a wave-meter.

As already explained, a loop of wire must be joined across the aerial and earth terminals of the tuner, and it will be seen that in some cases a greater number of turns is necessary than in others. The detector and telephones are used in connection with the multiple tuner as a means of detecting when a condition of resonance has been attained, but the connections are omitted in order to simplify the sketches.

Fig. 238 shows the method of exciting a plain aerial by means of the sparking buzzer. It is useful for determining the natural wave length of the aerial, when required as an indication of the amount of additional inductance necessary for a certain wave length.

Fig. 239 shows the method of exciting an aerial in series with a condenser by means of a sparking buzzer. It is useful for determining the value of the extra condenser when tuning for a short wave.

Fig. 240 shows the method of exciting an aerial in series

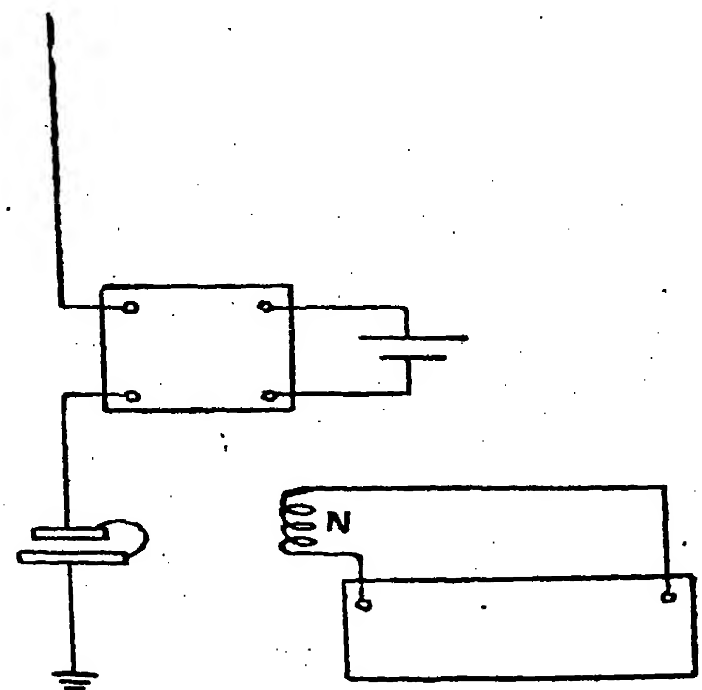


FIG. 238.—Excitation of Plain Aerial by means of Sparking Buzzer.—N=3 turns. Careful Buzzer adjustment is required. Good results may be obtained. Earth Arrester shorted.

with inductance by means of a shunted buzzer. It is useful for tuning the radiating circuit.

Fig. 241 ((*a*) and (*b*)) shows the method of exciting the closed oscillatory circuit by means of (*a*) a shunted buzzer, (*b*) a sparking buzzer. These methods are useful for tuning the closed oscillatory circuit.

In the first two cases the sparking buzzer is used, because the inductance energy with which a short length of straight wire can be charged is too small to produce detectable results.

As the shunted buzzer is of comparatively recent introduction, the majority of ship installations are supplied with the ordinary sparking buzzer, but the latter may be modified in a very simple manner.

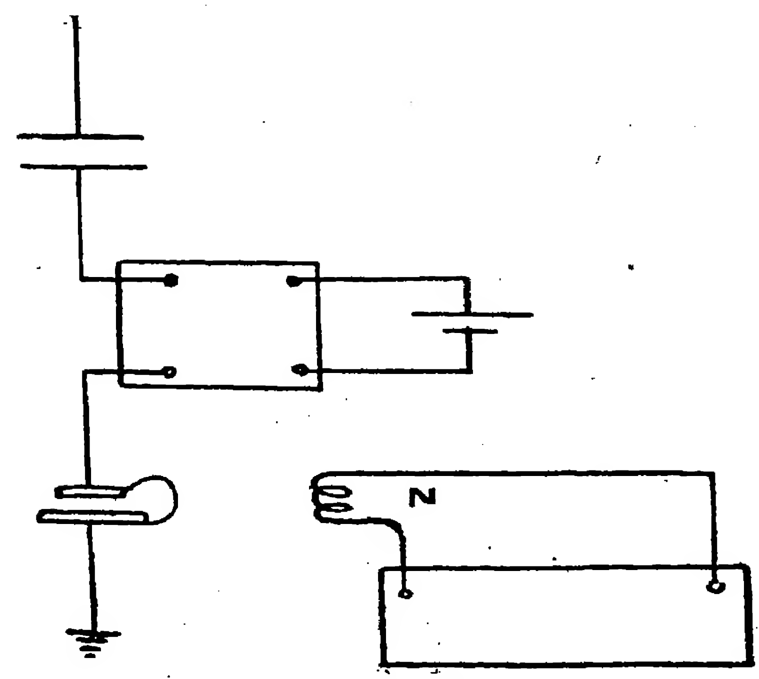


FIG. 239.—Excitation of Aerial with Condenser in series by means of Sparking Buzzer. N = 2 or 3 turns. Buzzer may be inserted above or below the Condenser. Arrester shorted. Good results may be obtained.

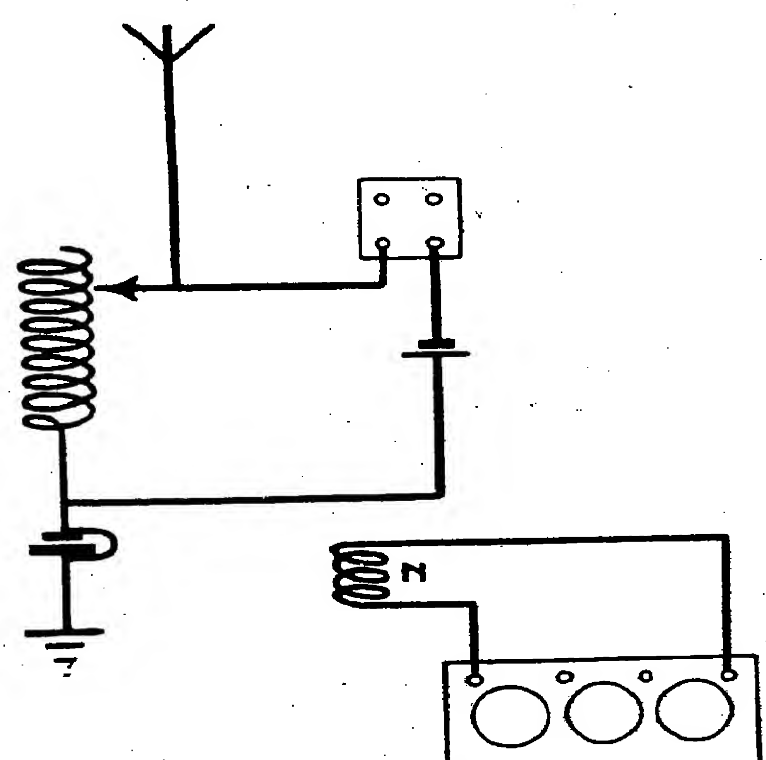


FIG. 240.—Excitation of Aerial with inductance in series by means of Shunted Buzzer. N = 14 turns. At least 4 turns of inductance must be buzzed. Good results may be obtained.

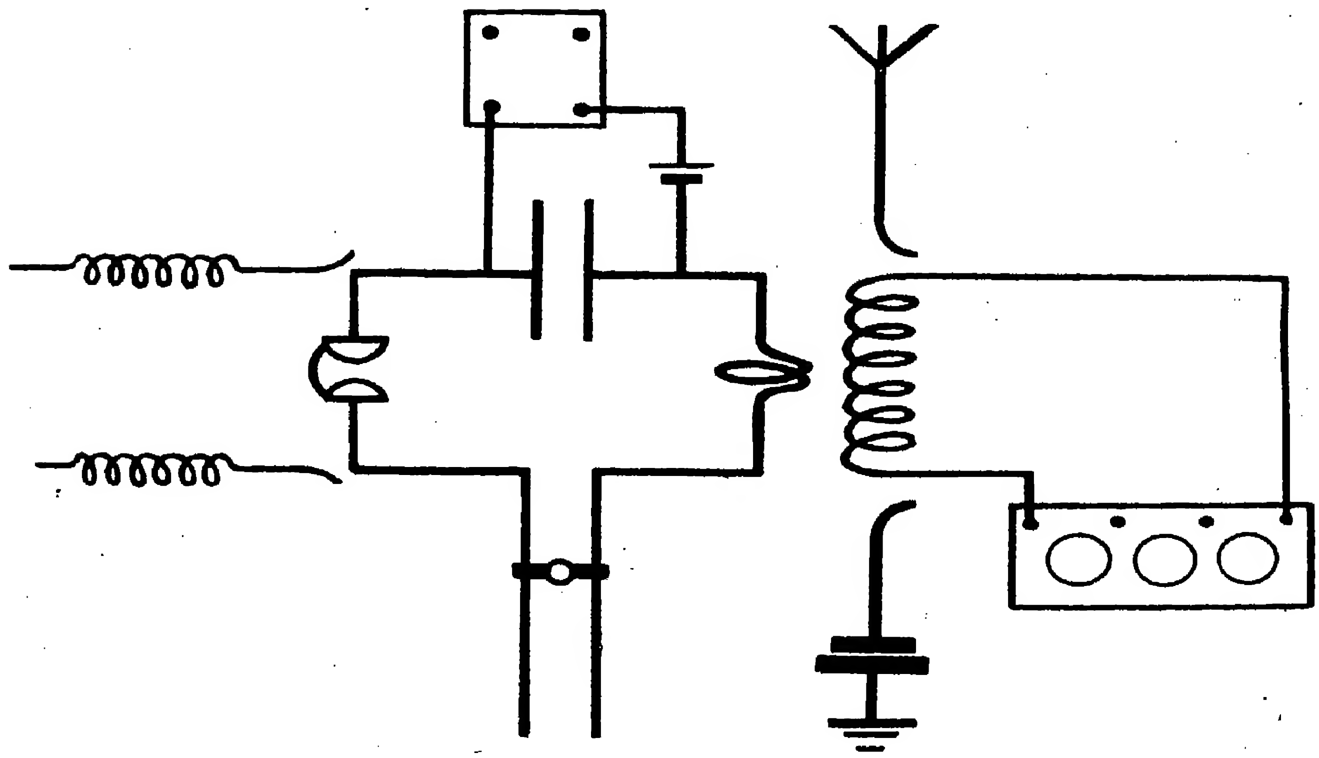
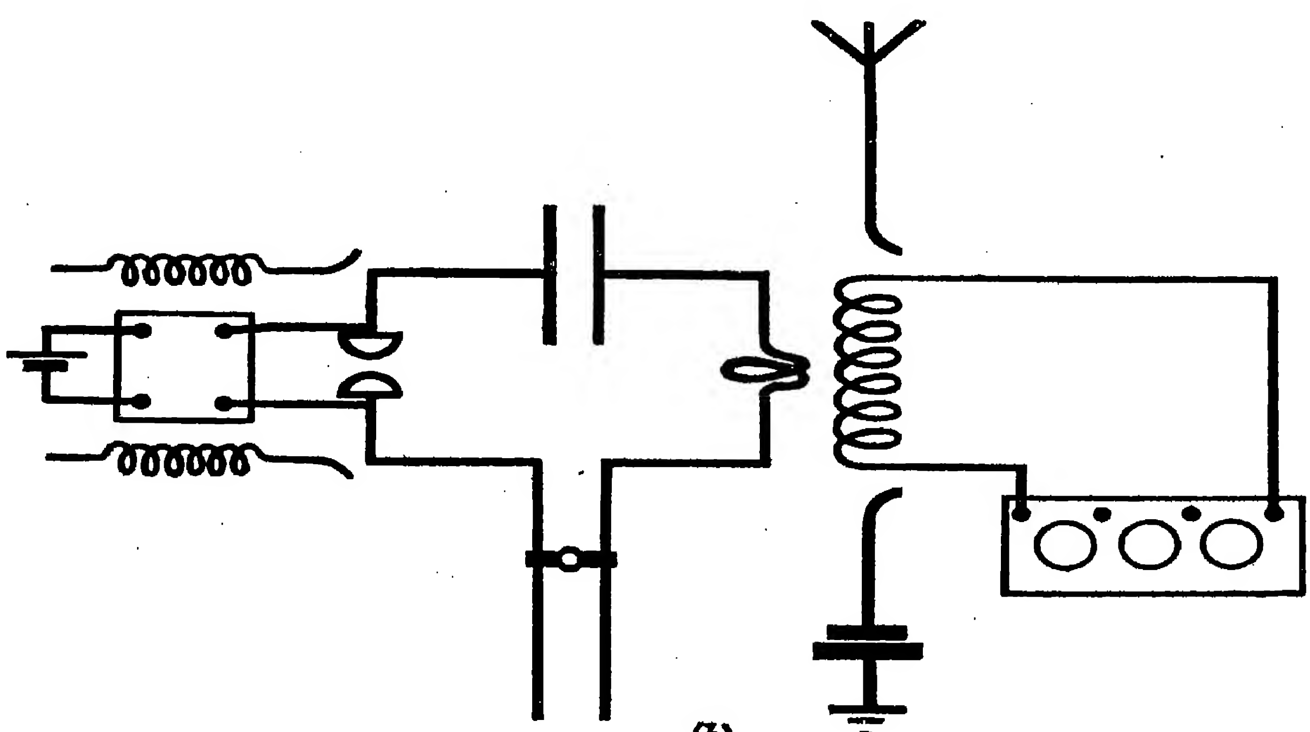


FIG. 241.—(*a*) Excitation of closed Oscillatory Circuit by means of Shunted Buzzer. Spark-gap shorted. Transformer disconnected. Jigger secondary disconnected from Aerial and Earth and connected to Tuner. Coupling rather loose. Good results obtained.



(*b*)

FIG. 241.—(*b*) Excitation of closed Oscillatory Circuit by means of Sparking Buzzer. Good results obtained. Signals stronger than in (*a*). Length of leads to buzzer may cause inaccuracy by altering the inductance of the circuit.

A resistance of from 5 to 10 ohms is a suitable value for the shunt for most buzzers. Failing other materials, 3 feet of the iron wire used for magnetic detector bands serves the purpose fairly well. It can be wound non-inductively on a match and tucked away under the magnet coils. In order that the resistance may be non-inductive, the length of wire must be doubled on itself at its middle point, and wound as shown in Fig. 242.

Multiple Tuner Faults.—It occasionally happens that, on account of having worked with too wide a micrometer spark gap, the adjustable aerial tuning condenser of the multiple tuner breaks down. In such an event the operator should not attempt to repair the condenser, as, on account of its delicate parts, he is more likely to do more harm than good. It may be useful, however, to know how to replace the faulty condenser with either the intermediate or detector tuning condenser. This interchanging of condensers renders the "tune" side of the instrument useless, but the operator will be able to manage

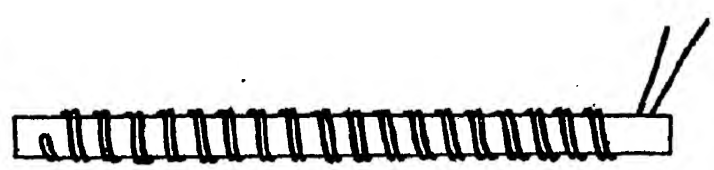


FIG. 242.—Improvised Shunt for Buzzer.

on the "stand bi" side until more efficient repairs can be made on reaching the home port.

Each condenser is fitted with two small black screws near the figure 5 on the scales. If the condenser be turned until the pointers indicate a reading of five divisions, and if these two screws be removed, it will be found that the heads of two other small screws are revealed. By using a small screwdriver—it must be small enough to pass through the holes in the top of the condenser—the second pair of screws may be removed. If the large brass nut in the centre of the condenser handle—the "blind" nut—be now removed, it will expose a fork nut. Unscrew this and the whole condenser may then be removed bodily from the rest of the instrument.

A FEW USEFUL HINTS.—Keep all parts of the "Bradfield" leading-in insulator clean. The rod should be removed at least once a week, and should be thoroughly cleaned from rust. Attention should be paid to the lock nuts, etc. If

these little matters are not attended to, the whole insulator may be ruined. The rod will be found to jamb, and to be removable only by smashing the ebonite tube. The thread of the lock nuts may become so badly worn that it will be impossible to make a good electrical connection. If the whole insulator be taken to pieces about once a month, attention can also be paid to the stuffing-box.

Spare "Bradfield" tubes should not be kept in a leaning position. They should be laid flat down on the deck or in a drawer, otherwise they are liable to bend, especially when in hot climates. It is difficult to pass the rod through a bent tube without breaking the tube.

All spare parts should be kept in a good condition. It is not advisable to keep such delicate spares as magnetic primary windings amongst a number of heavy coach screws, tools, etc.

A little care might be exercised in the maintenance of the repair outfit, as repairs are much more easily carried out when good tools are available.

See that both sides of the magnetic detector are always ready for instant use.

Remove all fuses when in port, as this is an effective way of preventing unauthorised and incompetent people from working the gear, should they obtain admission to the room in the operator's absence.

Keep all bare copper leads clean and bright. Do not try any such labour-saving devices as paint, enamel, etc.

Do not make the cabin look like a rag-shop or a nursery by sticking newspaper cuttings, etc., all over the bulkheads.

Do not spread oil indiscriminately over new instruments. It does not improve their appearance. A dry dusting brush or duster should be sufficient.

Do not be afraid of drawing attention to a leaking cabin. Nothing is so conducive to bad working as wet and dirty apparatus.

The discharger should be given careful attention. The occasional application of a duster by keeping the surface insulation in good condition will considerably prolong the life of the discharger. Renew the lime in the zinc tray occasionally, and keep the electrodes clean and smooth.

Keep the earth arresters clean—which does not imply any necessity to rub off the lacquer.

After a prolonged run, be careful to see that no part of the

apparatus has become unduly heated. Careful attention to this advice may lead to the detection of an incipient fault, and may prevent a serious fire taking place.

Use your nose as well as your eyes and ears to detect signs of burning or undue heating from electrical leakage, bad connections, and so on. Never leave any such symptom unaccounted for or unremedied.

Never put in the main switch before ascertaining that the handle of the starter is on the "off" position.

When working with a strange or new set of apparatus, examine the high tension and oscillatory circuits before closing the switch of the A.C. board.

Don't neglect your tuning-lamp as an indicator as to whether your apparatus is all in order.

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THE END

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